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RICE IN ABUNDANCE FOR ALL TIMES THROUGH RICE CLONE.

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(A possible one-grain rice revolution)

— A genetic forecast —

by

Dr. R.H. RICHHARIA, Ph. D. (Cantab.)

Ex-Director,

Central Rice Research Institute

CUTTACK

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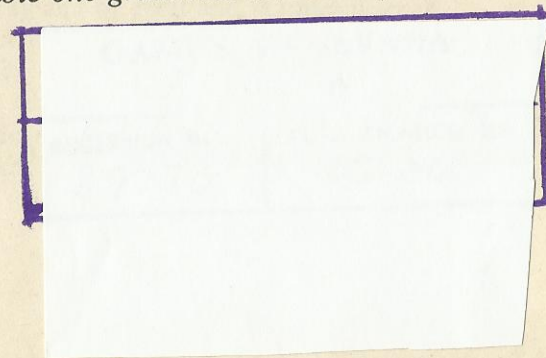
M.P. Rice Research Institute

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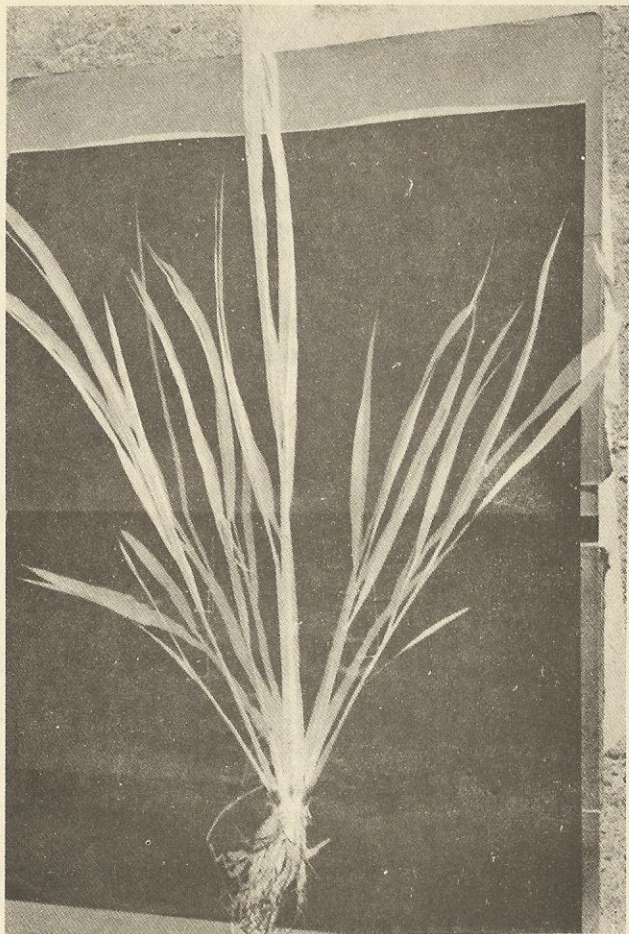
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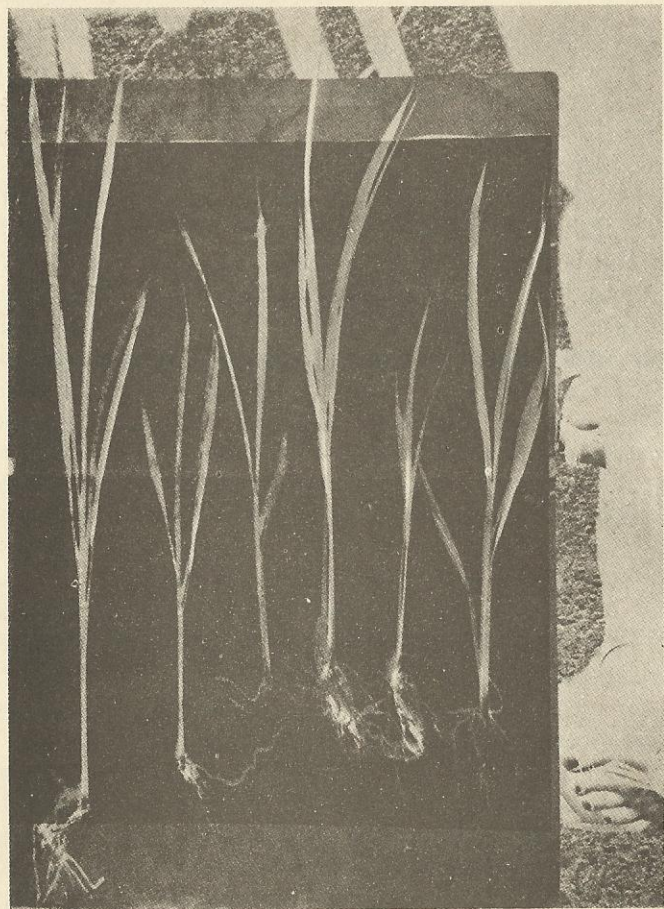
If thy aim be great and thy means small,
still act, for by action alone these can increase
to thee.

Care not for time and success. Act out
thy part, whether it be to fail or to prosper.

SRI AUROBINDO



A rice seedling, 38 days old, of a variety, *Kalya*, from Madhya Pradesh with normal tiller growth; raised at Gloria Land of Sri Aurobindo Ashram (1986).



Six tillers, separated from the rice seedling, shown in Figure on the left.

DEDICATION

This book is dedicated to the tribals of India....

FOREWORD (by a farmer)

Dr. Richharia's contributions, as a rice breeder, are well-known to the farmers in many parts of India. As a farmer who is involved in rice cultivation during the past 22 years, I have been keeping myself in touch with rice workers of his type. To quote his work as an example; some of the B.R. series of rice varieties which he evolved in Bihar during 40's and 50's are still popular among the rice farmers of that region. Further, the evolution of C.R. series of improved rices which he initiated during 1959-67 at Cuttack (as I was told during my visit to the Central Rice Research Institute, last year) has yielded some high yielding rice types which have suited many environments in the Country, *e.g.*, C.R.1014, a low-land, fine-grained and late maturing rice variety has become popular among the rice growers in Orissa and other eastern regions. His book, entitled 'Rices of India' with his Associate Dr. S. Govindaswami gives a glimpse of the richness of high yielding rice germplasm of our country.

I came in contact with Dr. Richharia personally first when he was invited by A.M.E.* of the Netherlands to deliver a lecture to the International Trainees at Pondicherry in 1985. After hearing him, I offered him all facilities to pursue his line of work on indigenous rice varieties with special reference to his plan of action on clonal propagation technology at the Gloria Land Farm of Sri Aurobindo Ashram. He has commenced his investigations

* Agriculture, Man, Ecology Foundation of the Netherlands.

with me with his 250 rice varieties, including some clustered types which he has brought from his collection of nearly 20 thousand cultivars of Madhya Pradesh.

In this book he gives many ideas which are well within the reach of rice farmers, such as rapid multiplication through clones to obtain higher rice production by normal planting, exploitation of hybrid vigour and hybrid rice, utilizing even wild rices directly to take advantage of resistance to diseases and pests and establishing rice gardens, all with the aid of clonal technology which attracted my attention as a rice farmer.

I feel, any idea which aims at increasing the production of rice which is World's most vital cereal food should be most welcome and more so from one who has devoted his life-time working with rice. I appeal to my farmer brethren to give a fair trial to the methods, suggested here.

I am indeed grateful to the Author for giving me the privilege to write this 'Foreword' which could go to very 'high-ups' but he preferred a rice farmer.

Sri Aurobindo Ashram,
Pondicherry,

May 18, 1987.

Manindra Pal
Gloria Land.

Mr. Manindra Pal is a practical farmer, managing Sri Aurobindo Ashram's 'Gloria Land' Farm of 40 hectares (100 acres) for the last 22 years with rice & banana as major crops, cultivated absolutely under organic manuring, associated with a dairy of 250 milch cows, He is always very keen to know and learn the latest developments in crop production technology with history behind them from whichever source possible.

Dr. R. H. Richharia
18-5-87.

ACKNOWLEDGEMENT

I bless my daughter Utpala and grand daughter Vinita for the proof reading, as much as they could do. For some of the drawings, I am grateful to the Drawing Department of Sri Aurobindo Ashram, Pondicherry. I also express my gratitude to my associates and the researchers whose work has been cited here. Further, I may be excused for the draw-backs which may be noticed in the text, caused by my limitations and constraints, both mental and financial.

To Mr. Saphal, Manager, All India Press, Pondicherry I express my indebtedness for taking keen interest in printing the book.

Dr. R. H. Richharia
18-5-87

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ABBREVIATIONS USED:

IARI	: Indian Agricultural Research Institute.
ICAR	: Indian Council of Agricultural Research
CRRI	: Central Rice Research Institute
MPRRI	: Madhya Pradesh Rice Research Institute
IRRI	: International Rice Research Institute

PREFACE

My experience and knowledge of the world literature on rice, including that available in the Vedic literature of ancient India and rice cultivation in tribal areas, indicate that (1) its single grain/stubble can yield over 40 quintals of rice within a period of 10 to 11 months (January-November), (2) it is possible to create the entire genetic variability in rice from its single grain by different techniques, now available, ensuring the re-establishment of the rice culture, even if the nuclear wars engulf the world, (3) Every rice cultivar has its utility for the welfare of human beings with potentials to give high yields in its environments with package of practices, worked out for individual cultivars and (4) Possibility of establishing perennial rice field gardens, involving suitable genotypes and agronomic base, ensuring every-day rice harvest aiming at even a hundred tonnes of rice per hectare annually to meet the challenge of the "Population bomb" (*) if it explodes, as estimated to be approximately 8 billion people by the year 2015 in the world. As it is, rice is the most important food crop of the world and with the gradual increase in the rice eating habit among the humans, rice would become a supreme food of the world population. Any attempts and suggestions advanced to improve the cause of rice production and productivity from any quarter should be most welcome, irrespective of the position of a worker whether he is a top scientist, a common researcher or a small farmer, growing rice with his single pair of bullocks and a wooden plough, producing

* The term used by Paul Ehrlich in his book, "The Population Bomb, 1968".

over 95 percent of our rice food in India. Apart from my other scientific activities, as a rice breeder, I have been working on this *Clonal Propagation Technology* and utility of the rice clones described here from the year 1942. It remains yet to be worked out, how the rice clones would respond in space. I do hope, the rice researchers and extension workers will follow up the work to initiate a silent rice revolution among the rice farmers. At the same time, we invite others to become rice producers at their residential terraces and in their compound gardens.

Govindpura
Bhopal
August 15, 1986.

R. H. Richharia

100 Kg = 1 quintal

CHAPTER I INTRODUCTION

Clonal propagation is one way to break through the conventional methods, being employed to increase rice productivity and take advantage of the latent energy of the rice plant, released to meet the challenge of the growing population in the country, as well as to exploit export potential of over 300 quality-rices which remain neglected (not even one percent exported). There exists a great scope in this direction as the rice eating habit is fast increasing among the humans.

Investigations have conclusively established the superiority in grain production of vegetatively propagated plants (clones) over normal seed plants in respect of environmental stress and drought, comparatively non-lodging habit, resistance to diseases, pests, flood and salinity, ultimately to produce more grains per unit area. It indicates a sort of chain reaction.

There is no other field technology which can allow seed multiplication so rapidly than this method which enables a single paddy grain or a single stubble, multiplied to obtain over forty quintals of grains within ten to eleven months (January to November), depending on the variety utilized and resources made available. If the tissue culture technique is applied at the vegetative phase, there is no limit to multiply clones and ultimately grain yield. Work on this technology of clonal propagation (also known as vegetative propagation) and on individual tiller breeding in rice has been carried out for quite some time by the author and his associates, beginning with 1942, but more intensively after 1958 and a series of papers have appeared. Its importance in rice breeding and as a practical means of exploiting hybrid vigour in Rice was worked out as far back as 1960.

At a Seminar held at the International Rice Research Institute (Philippines) in 1963, the technique was also explained and upto date knowledge on the subject then available was recorded (Appendix II).

The clonal technology now provides an easy solution to exploit hybrid vigour in rice even utilising male steriles and semi-male steriles of local origin, available in plenty in the locality where the author has been working in recent years. The method can be applied to prevent depression in grain yield, caused by intensive inbreeding in a rice variety by employing its eco-types in the crossing programme.

The technology has succeeded because of the perennating habit in the rice cultivars and the trigger action in respect of growth and vigour, stimulated every time the tiller is separated. "It appears that tiller separation retards the action of certain physiological inhibiting factor (Say hormone) which controls the growth of secondary and tertiary tillers or in other words, in rice the tiller separation apical dominance is reduced."

This bulletin records briefly the work carried out by the author and his associates during different periods beginning with 1942 at different places.

The technique was extensively applied for agronomic, physiological and genetical studies at the Central Rice Research Institute (Richharia, 1960, 62; Richharia and Misro, 1960; Richharia and Patnaik, 1963; Richharia, Mahapatra and Manna, 1964 and Scientific reports of the period *etc.*)

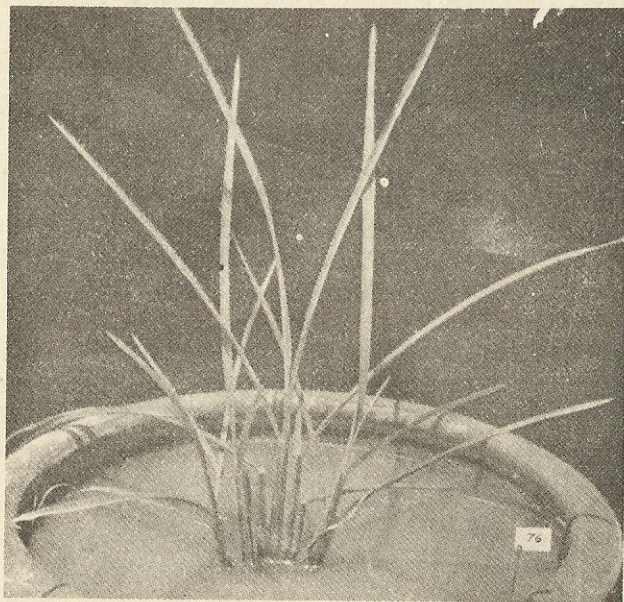
CHAPTER II

DESCRIPTION OF CLONAL PROPAGATION TECHNOLOGY AND ITS UTILITY

INDIVIDUAL RICE GRAINS AS A BASE:

Paddy grains are picked up and put for germination in an earthen pot. They germinate and begin to grow, as seen in Fig. 1, with two grains. The same two seedlings throw out tillers, as depicted in Fig. 2, after about 10 to 12 days, depending on the season. The tillers can be separated when they are fairly strong, about 20 days after, by carefully detaching them one by one by finger nails as shown in Figs. 3&4, preferably by thumb's nail or by a sharp scalpel or razor blade. The separated tillers should be immediately transferred back in the earthen pot which is to be well manured with enough moisture. Fig. 5 depicts the six separated tillers (now known as clones) three from each of the two seedlings. The individual tillers (clones) shown in Fig. 5, grow and again produce tillers in varying numbers, every about 15 days after (Fig. 6); here three tillers are seen in every case. The process of separation is repeated at intervals, depending on the growth and development of tillers, till the normal time of transplanting reaches in July-August. It is observed that the period of separation (intervals) is very much reduced *i.e.*, the rate of growth is very much accelerated during June-July. Any number of clones can be raised and multiplied from a single seedling or a few of them (if a beginning is made fairly early, say February when the winter temperature begins to rise)

transplanted in July-August to cover an acre of rice field and a full crop of rice harvested by November to obtain a huge quantity of pure seeds, as stated in some cases, recorded later. A careful examination of the arrangement of tiller formation at early stages would show that it is linear as seen in the accompanying figure. This condition facilitates tiller separation.



Linear arrangement of tillers at early growth. (Original Fig. 5, reproduced from Richharia, 1961: P. 27).

In this manner, pure seeds can be multiplied by this clonal propagation technology, described above and a normal crop of rice can be raised during the following season from seeds (obtained from the clones) which give higher production than the yields obtained from seed to seed crop. This is mainly because the grains, obtained from clones are fully matured, healthy and filled up with the least percentage of chaffy grains. This is also due to physiological efficiency of the tiller plants. It is also now known that nutrient uptake of tiller crop and seed crop is more or less identical.

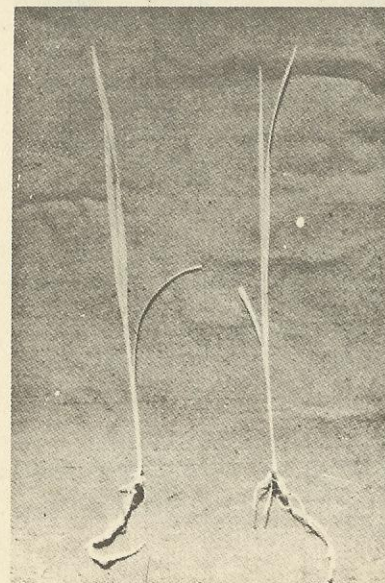


Fig. 1: Two rice seedlings, six to seven days old.

The individual rice grain can also be a hybrid seed for F_1 plant which can be expanded clonally to obtain enough seeds to raise a full rice crop of F_2 generation, exploiting remnant hybrid vigour in later generation, as described later in detail. The same procedure may be followed with the stubbles, dug up from the field, or with an aged seedling (Fig. 7)

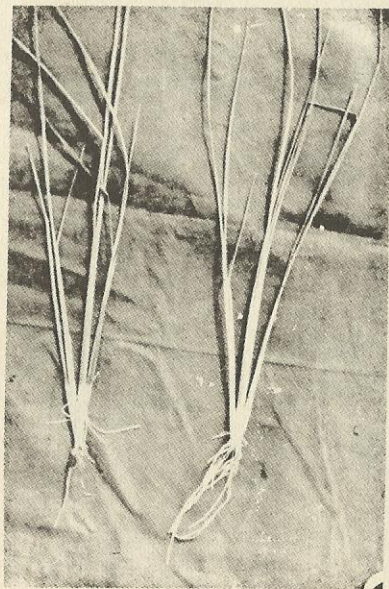


Fig. 2: The two seedlings (shown in Fig. 1) throwing out three tillers each

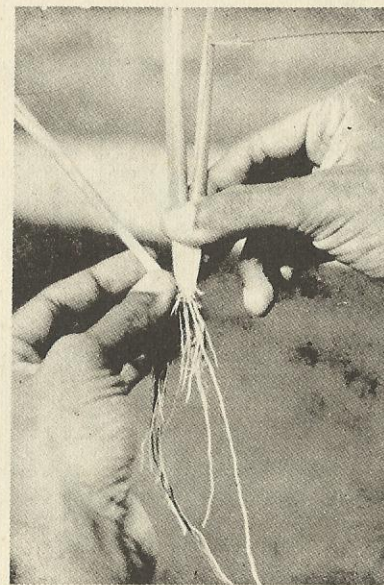


Fig. 3: Demonstration of the process of separating the tillers (about 20 days old)

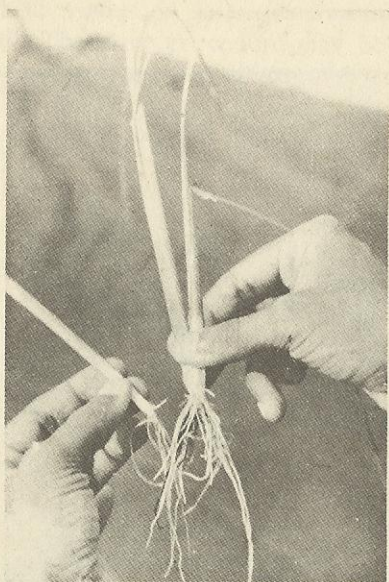


Fig. 4: One tiller, separated (now to be known as a clone) from the rest of the two. This can be done carefully either with the aid of finger nails (preferably thumb nail) or by a sharp scalpel, knife or a razor blade. Separated tillers, to be immediately transferred back in a well-manured and drained earthen pot with sufficient moisture.

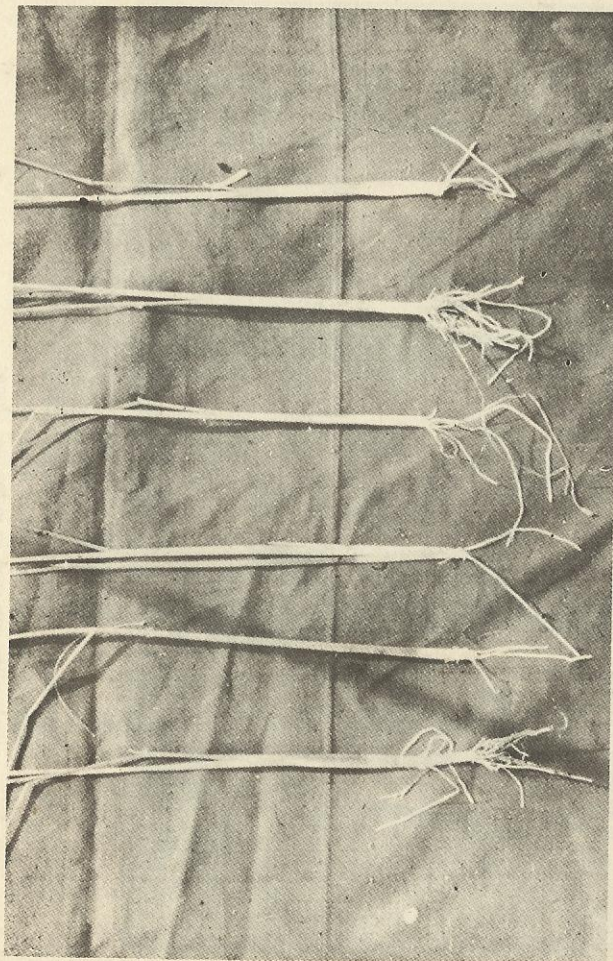


Fig. 5: Depicts the six separated tillers Clones, three from each of the two seedlings, seen in Fig. 2.

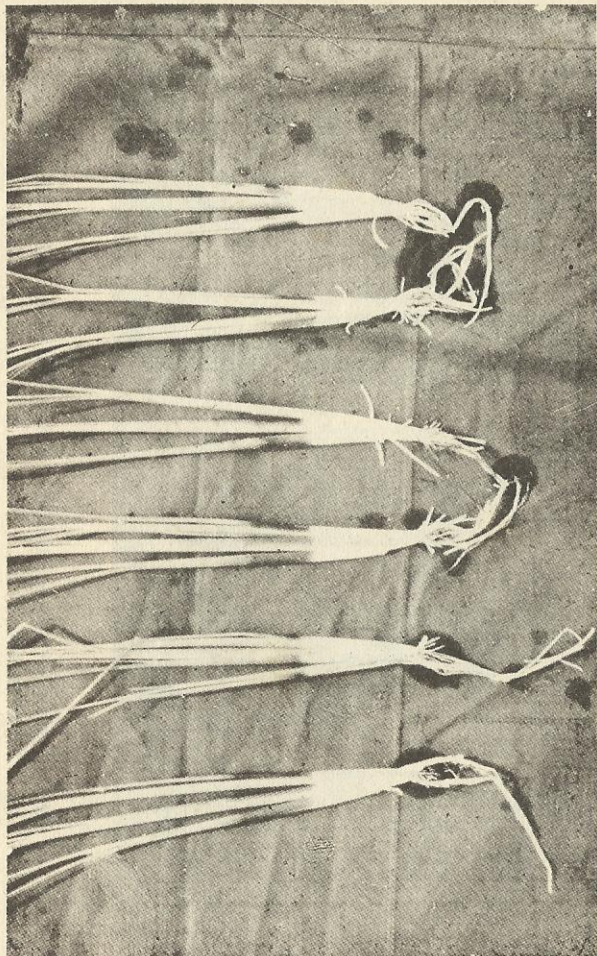


Fig. 6: Individual tillers (clones) shown in Fig. 5 grow and again produce tillers in varying numbers in nearly every 15 days interval. Here only three tillers are seen in individual clones.

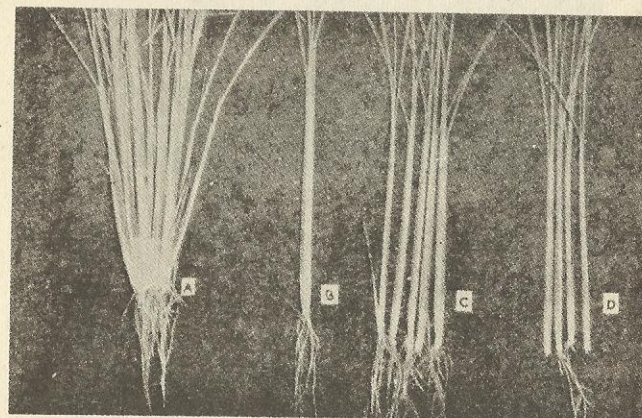


Fig. 7: Tiller separation in rice to exploit vegetative propagation. (A) A single plant of a rice variety, B.A.M. 9 of Orissa, before tiller separation; (B) Main tiller; (C) Primary tillers; and (D) Secondary tillers, all separated from the rice plant shown in (A). Every tiller behaves as a single plant, throwing out again a number of tillers.

(Reproduced from Richharia, 1964a: p. 299)

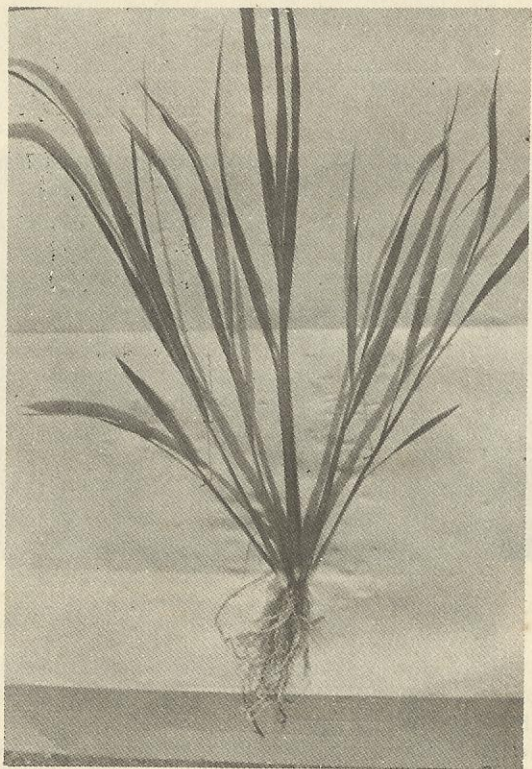


Fig — A

A rice seedling, 38 days old, of a variety, *Kolya*, from Madhya Pradesh with tiller growth, raised at Gloria Land of Sri Aurobindo Ashram.



Fig — B

Six tillers (clones) separated from the rice seedling, shown in Fig. A.

The period inbetween the formation of 3 to 4 primary tillers differs from variety to variety, on the same pattern as maximum tillering stage or the stage of peak vegetative growth which is observed to be independent of the varieties, nearly obtained in about 70-80 days after sowing in late maturing types. The separation of the tillers can be continued upto that maximum phase at intervals, when 3-4 primary tillers are thrown out. The separated primary tiller functions as the mother tiller for the following split. Since in the early duration varieties, beginning of the reproductive growth stage closely follows the maximum tillering stage, the number of splits have to be limited, as the final split has to be carried out much earlier before the maximum tillering stage reaches. Whereas, in the medium and late varieties there is a time-lag between the peak vegetative growth stage and the reproductive stage, hence separation of tillers can continue upto that stage (inclusive). Therefore the clone populations, raised in medium and late varieties, are higher than those, raised in early duration varieties.

To illustrate this technology, one selected seed from a photosensitive rice variety, *Jbs 929*, was used to raise a basic population of 1014 tiller plants at C.R.R.I., (Cuttack) during 1965 under normal field conditions within a season as recorded in the table below and the pattern and sequence of tiller production derived from a single seed, reproduced in Fig. 8.

Rate of tiller production from a single seed by periodical cloning in rice

Variety	First split	No. of tillers	Second split	No. of tillers	Third split	No. of tillers	Fourth split	No. of tillers	Fifth split	No. of tillers	Dead tillers	Total tillers
JBS 929	30 days after sowing	M P1 P2 P3	60 days after sowing	8 6 5 1	90 days after sowing	25 17 12 3	120 days after sowing	66 74 50 10	150 days after sowing	389 344 211 22	12 19 nil 17	401 363 211 39
Total		4		20		57		200		966	48	1014

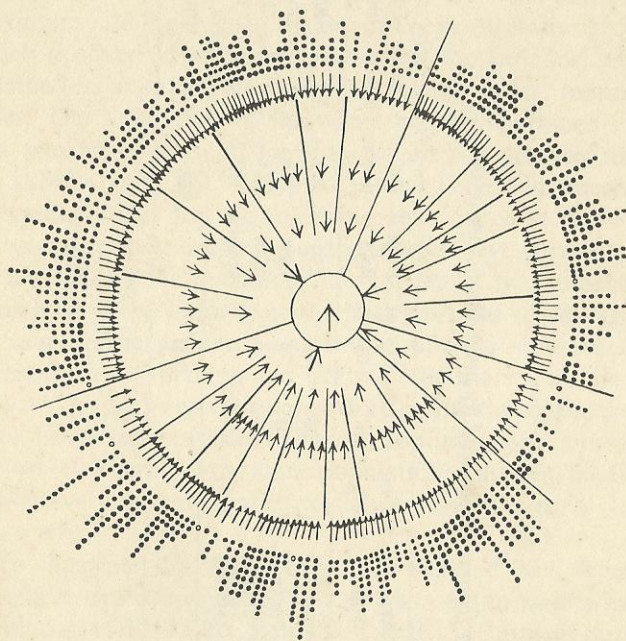


Fig. 8. Clonal spectrum derived from a single seed of JBS 929 (closed dots = tiller plants; open dots = dead plants). Each circle represents thirty days interval and the total plants produced at clonal separation.

The table and Fig. 8 provided by Dr. K. Pavithran personally, later published (Pavithran, 1975).

The perennating habit of the Rice plant and its photo-sensitivity character have been utilized in developing the clonal propagation field technology, as also mentioned earlier. Studies on the distribution of varieties with perennating habit indicated a high degree of perennation for the early varieties of the temperate zone and the late varieties of the tropical zone.

The photo-period sensitivity of a rice variety dominates over the temperature sensitivity in high photo-sensitive varieties. In low photo-sensitive types, temperature sensitivity dominates over photo-sensitivity. These facts have been also utilised in evolving clonal propagation technology on a mass scale.

Whereas tiller formation at the successive stages, is a varietal character, vigour caused by hybridization also accelerates tiller formation rapidly in the hybridized grain.

Some of the findings of investigations on the various aspects of the technique of Clonal propagation, conducted at CRRI, Cuttack, under the guidance of the Author by different rice researchers are reproduced below for ready reference: (*c.f.*, Richharia, 1964b), Experiments, carried out in other rice growing States, are mentioned later in Chapter VII. Other technical reports of the Institute after 1959 upto 1967 especially on the subject may also be consulted.

(1) As already stated above the separation of the tillers is done at minimum possible intervals, the suitable stage of separation being that when the number of tillers reach 3 to 4. This stage embraces a mother tiller and the primary tillers only. If the seed plant is left to grow longer (without splits), secondary and tertiary tillers are thrown out. If the season

allows transplanting, the separation of all the tillers can be done, only once and directly planted, including the tertiary once also which (otherwise remain sterile when left in the plant undisturbed) would prove to be fertile as well. The strength of the total number of clones, produced before the final planting, is a varietal character, irrespective of maturity period, directly proportional to the tillering capacity of a type, as expressed under prevailing environmental situation which may vary from season to season in different years as exemplified by the following figures:

Total number of tillers produced per plant in different years:—

Rice Variety	Year		
	1959	1960	1961
Pib. 10	10.2	22.2	14.5
CH 45	12.4	29.6	29.4
T. 1145	11.8	36.7	28.3
T. 141	12.4	29.5	29.2
T. 1242	11.4	29.5	29.2
GEB 24	16.1	47.7	38.9

Maximum number of clones could be multiplied to cover a large area in *Geb. 24*, as also in CR 1014, a profuse tillering variety. Sensitive and non-sensitive character of a variety, besides the tillering character also determines the expansion of the clones.

(2) In some varieties, such as *Geb. 24*, a little salt application produces more tillers. In an experiment with the same variety, the highest number of tillers were produced when the

plant was 70 days old; whereas with other varieties, such as *S.R. 26 B* and *T. 141*, practically no response to this treatment was observed. For such treatments, therefore, varietal response exists. Treatments with certain enzymes and hormones need investigations to exploit potentials of tiller production in individual rice types.

(3) Some distinct characters, such as the leaf-blade colour with the help of which some phenotypes can be separated at the seedling stage in the seed-bed, can be utilized, linking them with productivity *e.g.*, in a cross *JBS. 120* (purple) X *T. 141*, (green) the F_1 plant was multiplied vegetatively and the seeds harvested for F_2 generation. The seedlings raised at the seed-bed stage were easily identified as green, purple and mixed plants and planted separately:

Green plants recorded as much as 3666 kg/ha. (3273 lb/ac) whereas the purple plants gave only 900 kg/ha (804 lb/ac). The mixed plants yielded 3250 kg/ha (2900 lb/ac) (also see p. 71)

(4) A series of observational tests were conducted with pure types raising seedlings by normal method and also by vegetative propagation. The treatments under study with the results obtained in each trial are given below:—

Yield of Grain in kg/ha.

Treatments	Yield	% of control
1. <i>A.C.2156</i> normal seedlings	854	100.0
2. <i>A.C. Veg.</i> propagated	1998	233.9

Yield of grain in kg/ha.

Treatments	Yield	% of control
1. <i>GEB.24</i> normal seedlings	1221	100.0
2. <i>GEB.24</i> seedlings raised from the seed obtained from Veg. propagated crop	1282	105.0
3. <i>G.E.B.24</i> Veg. propagated seedlings	1752	143.5

The vegetatively propagated crop was found to yield 43.5% more than the normal crop during the main season. It is worth mentioning here that the seedlings obtained from the seeds of a vegetatively propagated crop yielded about 9% over the normal seedlings during the second crop season (January-April 1963) as against 5% in the main season (June to December 1963). (also see item 11)

From other experiments, conducted it was observed that the increased yield, obtained by clonal propagation varied with rice varieties and ranged from 17 to 61 per cent as compared with the culture, raised from normal rice seedlings.

(5) *Multiplication by clonal propagation within the season*

With a view to know how much area could be covered by a single plant, the seeds obtained from the single plant, the seeds obtained from the separated tillers, and the stubble obtained after the harvest of the plant, were grown. A high yielding culture (F⁶)* in the Cross *T.90* × *W.113-6* was utilised

*Designated as CR 1014 in 1963.

for this purpose. The number of seedlings obtained from each, the area covered and the yield obtained from each category are given below:—

1. Multiplied from the stubble.	2. Multiplied from Original Seeds	3. Multiplied from the seeds obtained from Tillers
One stubble taken and split and planted continuously till 6-8-63 (7 splits).	Seeds sown originally during May and split at intervals till 17-8-63 (4 splits).	Seeds sown originally on 30-4-63 and split at intervals till 17-8-63 (5 splits).
Final planting 63,945 plants, planted 9" × 6".	Final planting 32,078 plants planted 9" × 6".	Final planting 13,732 plants, planted 9" × 6".
Area covered 0.80ac. (0.32 ha.).	Area covered 0.35ac (0.14 ha.).	Area covered 0.15ac. (0.06 ha.).
Yield 727.7kg.	Yield 373kg.	Yield 212kg.
Yield/ha. 2,274 kg.	Yield/ha. 2,664kg.	Yield/ha. 3,533kg.

(6) During the main crop season of the year (1963) at *CRR I* field experiments were conducted with normal and vegetatively propagated plants in two varieties *T.141* and *GEB.24*, in an attempt to find out the cause of increased grain yield in the vegetatively propagated crop. The field received a uniform application of 30 kg. each of nitrogen and phosphorus per hectare at the time of final puddling. Data on grain yield and nutrients removed are summarized below:

Yield and nutrients removed by vegetatively propagated and normally transplanted rice

Variety	Type of crop		Yield kg/ha	Nutrients removed kg/ha.		
				N	P	K
T.141	Normal seedling	grain	3029	30	8	8
		straw	5417	26	7	142
		Total	8446	56	15	150
	Vegetatively propagated (within season)	grain	3736	38	12	7
		straw	5454	16	6	104
		Total	9190	54	18	111
	Seedlings of same age as vegetatively propa- gated	grain	3026	29	9	8
		straw	4960	17	6	165
		Total	7986	46	15	173
GEB.24	Normal seedling	grain	3219	38	10	10
		straw	5128	15	7	121
		Total	8347	53	17	131
	Vegetatively propagated from stubbles	grain	3455	38	10	6
		straw	5078	17	5	121
		Total	8533	55	15	127

Results show that the vegetatively propagated crop in both the varieties gave an increased yield of grain and straw as compared with the normally transplanted crop. In the variety T.141 normally planted seedlings of the same age as that of the vegetatively propagated crop also gave an yield comparable to that of the normal crop.

Data on the amounts of nitrogen, phosphorus and potassium removed by the different types of crop in the two varieties are also given. The amount of nitrogen and phosphorus removed by the total crop (grain plus straw) was more or less the same for the different types of crop in the two varieties. In T.141, however, the fraction of these two nutrients translocated to the grain was more in the vegetatively propagated crop than in the normally planted crop. No such difference was obtained in GEB. 24 where the increase in grain yield was comparatively less. Data on potassium removal did not show any definite trend.

(7) It is also observed that the clones respond to fertilization and yield better than the normal seedlings. Its (clonal propagation) application to HYVs of indigenous origin would give still higher yields.

(8) High Degree of sterility is often observed in some cross-combinations in rice and it is difficult to obtain enough seeds. Vegetatively multiplied F_1 material would yield enough seeds for F_2 generation e.g., The following crosses showed high degree of sterility, but by vegetative propagation, enough F_1 seeds for F_2 generation could be collected during 1963 for detailed studies.

(GEB. 24 $\times$ W. 114) $\times$ T. 141

(Bam. 6 $\times$ Asahi) $\times$ Bam. 9

(W. 114 $\times$ T. 141) $\times$ Ptb. 10

(T. 812 $\times$ Asahi) $\times$ (Norin 6 $\times$ GEB. 24)

(GEB. 24 $\times$ Asahi) $\times$ T. 812 $\times$ Asahi)

(T. 1145 × Taihoku. 6) × (HS. 19 × Taihoku. 6)
 (T. 812 × Asahi) × (GEB. 24 × Asahi)
 (Bam. 9 × Norin. 18) × (T. 1145 × Taihoku. 6)

Recombination of any amount of genetic combination can be brought about and enough seeds obtained for the next generation by this method for studies.

Back-crossed Seed plants can also be multiplied clonally. Even seeds from inter-specific hybrids which prove sterile can be obtained, if vegetative propagation is resorted to. Thus occurrence of high sterility in rice crosses is no problem now to exploit any material.

(9) To find out the possibility of introducing the practice of clonal propagation in rice under saline soils, a preliminary investigation was carried out at the Saline Resistant Rice Research Sub-station, Canning Town (West Bengal) during 1963. There was an indication that tiller separation and retransplanting can be done upto third week of August without any appreciable reduction in yield and crops raised, utilizing clones of rice varieties, *Geb. 24*, *T. 141* and *SR 26 B* which gave higher yields. It may thus be possible to raise a full crop of rice of any rice cultivar, if the transplanting is done, utilizing its clones only. As already recorded under item 2 that application of a little salt produces more tillers, but this is again a varietal character *e.g.*, *Geb. 24* responds to salt treatment, whereas there was practically no response with *SR 26 B* and *T. 141*.

It may again be recorded that response to clonal propagation is a varietal character *i.e.*, the population of clones raised by repeated separation at regular intervals differs from variety to variety and vigour accelerates tiller formation rapidly in hybrids.

(10) Different types of vegetatively propagated plants X Varieties.

In 1962 this experiment was transplanted on 30th August, while in 1963 the experiment was planted in July. Three types of seedlings were compared, viz., (1) Vegetatively propagated plants (Tiller crop) (2) Unpropagated seedlings of the same age as (1) and (3) normal (one month old) seedlings. The results are presented below:—

Variety	Date of planting	Vegetatively propagated crop.	Unpropagated crop.	Kg/ha	
				Normal crop.	Mean
T. 141	16th July	3848	3251	2901	3333
Geb. 24	16th July	4115	3407	2975	3499

Vegetatively propagated crop gave higher yields in both varieties, as compared to other treatments.

(11) Yield trial with seed, obtained from the tiller crop as compared with the crop from seed of normal and unpropagated seedlings.

This trial was especially initiated to observe whether there are any yield differences between crops raised from the seed of tiller crop, normal crop and unpropagated crop. The results are presented below:

Treatment	Yield in kg/ha		Percentage of (normal crop)	
	T. 141	T. 90	T. 141	T. 90
1) Seeds obtained from clones	3326	2631	114.0	105.9
2) Seeds obtained from unpropagated plants of the same age.	2832	2600	97.0	104.7
3) Seeds obtained from Normal seedlings.	2917	2485	100.0	100.0

An increase in yield is obtained by utilizing the seeds from the clone/Tiller plants of the same variety with varietal differences in *T.141* and *T.90*. This has a special significance to increase rice production and to facilitate the multiplication of improved seeds (also see item 4).

(12) Incidence of Pests in Clonal-Propagated Rice

1. *Gallfly*.—Investigations, conducted during 1962, showed that no difference in susceptibility exists between crops grown from seed and those grown from clonal-propagated tillers, though the grain yield was higher in the latter. The investigation was repeated to study the susceptibility, tillering and yielding capacity of crops raised from seed and from split tillers of seedlings of variety *BAM*. 9.

Sixty days old seedlings were split and the tillers were sorted out as mother (T_2), primary (T_3) and secondary (T_4). These unassorted tillers (T_6), unsplit whole plants of 60 days age (T_1) and unsplit seedlings of 30 days age (T_5) were planted in a randomised block in four replications. Gallfly incidence was esti-

mated by drawing samples. The data on incidence, yield and yield attributes are given in the Table below:

Incidence of gallfly in clonal and seed propagated rice crops

Method of propagation of rice crop	Observation on 31-10-63		Mean No. of earbearing tillers in samples of 16 plants	Yield in kg/ha	Yield in lbs/acre
	Tillers	Gallfly incidence			
(T_1) Unsplit whole plants	540.5	11.91	305.5	4515.5	4128.88
(T_2) Primary tillers	480.0	13.50	287.5	3555.5	3172.09
(T_3) Secondary tillers	505.0	14.13	256.5	1616.2	1442.25
(T_4) Tertiary tillers	644.0	16.59	229.0	2111.1	1883.63
(T_5) Seed propagated	667.0	15.71	170.5	642.4	573.92
(T_6) Mixed tillers of T_7 and (T_3) as above	495.0	11.08	233.5	1565.7	1396.37

Though there was no significant difference in incidence between treatments (T_1) and (T_6), (T_4) showed higher incidence than the other treatments. Maximum number of tillers was found in (T_5) followed by (T_4). In treatments (T_1) and (T_2) the number of tillers was low. The mean number of ear-bearing tillers was highest in (T_1) followed by (T_2) which resulted in very high yields. (T_5) recorded the lowest yield. It was indicated that regardless of the degree of susceptibility of crops raised by the different methods, there was significant increase in yields by clonal propagation method.

2. *Stem borers*.—Sixty days old seedlings of variety *Mtu*. 15 were split and separated into mother tillers (T_1), primary tillers (T_2) and secondary tillers (T_3); these and unsplit seed-

Incidence of stem borers in clonal and seed propagated rice crops

Method of propagation of rice crop (Treatments)	Percentage of Borer attacked tillers	Percentage White Ear- heads	Percentage Ear-bearing tillers	Height of tillers in cms.	Length of panicles in cms.	Sub-plot yield Kg. (Mean)	Yield in lb/acre	Yield in Kg/ha
T-Mother tillers	15.29	6.88	65.15	114.57	22.89	1.245	1086.62	1218.20
tr Primary tillers	17.31	11.16	75.79	109.00	24.27	1.100	960.03	1076.30
T ₁ Secondary tillers (P ₂ or P ₁ S)	11.45	18.29	77.78	103.85	22.39	0.550	480.01	538.20
T ₄ Seed propagated	21.01	57.61	83.92	96.44	20.69	0.455	397.20	455.20

ings of 30 days age (T₄) were planted in a randomised block. Stem borer incidence was estimated at the growth stage and at heading stage of crops by drawing samples. The yields and yield attributes together with the data on borer incidence are given in the table below:

Borer incidence was highest in (T₄) followed by (T₂), (T₁) and (T₃), at the growth stage resulting in dead hearts. At the heading stage, the percentage of white ear-heads was also highest in (T₄). The number of ear-bearing tillers was highest in (T₄) followed by (T₃), (T₂) and (T₁). The height of tillers was in the following descending order: (T₁), (T₂), (T₃) and (T₄). The length of the panicles was maximum in (T₂). Due to heavy incidence or borers in treatments (T₄) and (T₃); the yields were lower than in the other two treatments. All the treatments, however, gave increased yields over (T₄).

It may thus be possible to protect the rice crop from the attack of insect pests, particularly in endemic areas *e.g.*, endemic areas, of gallmidge in the Bangoli tract of Chhatisgarh (Raipur district of Madhya Pradesh) can be protected and normal rice crop raised, if the clones of the rice varieties being grown there, are utilized.

CHAPTER III

APPLICATION OF CLONAL PROPAGATION TECHNOLOGY IN OTHER DIFFERENT WAYS

(1) Individual rice grains as a base

In Chapter II, it has been described how a beginning can be made with the individual rice grains to raise clones. By repeated separation of clones it is possible to increase the clone plant population to any extent within a season. If a beginning is made a little earlier with suitable varieties, it has been found possible to raise enough clones to cover nearly an acre of transplanted area in the proper time to yield nearly 35 to 40 quintals of rice grains in some varieties at the end of the season, for normal cropping during the following season. These findings carry special significance to raise healthy seeds for raising normal rice crop with increased productivity, explained under items 4 and 11 of chapter II and for exploiting hybrid vigour in rice recorded in Chapter VI.

(2) *A live-stubble of rice plant removed from the field after harvest during October-December.*

After the crop is harvested during the period between October and December, the stubbles begin to sprout after a few days. One or more selected stubbles are dug up after the soil is moistened, removed from the field carefully and transferred in an earthen pot or a seed bed with abundance of moisture. When the tillers begin to grow they are separated and replanted. The process of splitting the tillers continues as and when the tillers can be conveniently separated.

In an experiment at C.R.R.I., Cuttack, during 1961-62 a stubble of a fixed rice culture C.R. 1014 (T. 90 × W. 113)-6,

resistant to lodging and high tillering was removed and the sprouted tillers, counted to be 72 (50 ear-bearing and 22 non-ear bearing) were planted in a well-manured plot with good irrigation in the last week of December. The first split was done in January, followed by separating the tillers at intervals which varied according to the growth of the clones. The procedure continued upto the middle of August, when the final transplanting was done, covering quite a big area, yielding about 20 quintals of paddy grains when the crop was harvested at the end of November. It is a non-lodging type with white and fine rice and a high hulling percentage (78), best suited to low rice lands of Orissa with high yield potential. The variety was accepted for extension in Orissa on a war footing with the vegetative propagation technology as an additional tool to increase plant population. The seeds of the variety were distributed in packets (containing two ounces of grains) among the rice farmers of Orissa all over by the Department of Agriculture of the State Government in April-May. The Extension workers and groups of the rice farmers were also trained to raise clones and multiply them to cover larger areas for seed production within that season for raising rice crop by normal method during the following year. This is an excellent example how any new rice variety can be spread rapidly in a rice region within a season by taking advantage of the technology of clonal propagation to take advantage of increased rice production within one or two seasons. An advantage can also be taken by distributing clones among the rice farmers in addition to seeds. This technology has been adopted by some progressive rice farmers of Orissa and elsewhere. A number of experiments have been conducted and it has been found that ordinarily it is possible to propagate a single stubble (with about 20 to 30 separated tillers) to a considerable bulk to occupy about half an acre of

transplanted rice land in 4 to 5 splits, between January and July.

Separating the tillers in the standing crop of rice, manually/mechanically can also be carried out in different ways, as explained below under items 3, 4 and 5.

(3) *An improved ratooning system:—*

Ratooning in rice is known and is practised in many rice regions in the country. Charak's writings indicate that the system was known from that period, as far back as 400 BC. It means, leaving the stubbles in the field undisturbed, after harvesting the main rice crop. and by doing so, some under developed tillers sprout up and grow rapidly to produce panicles with developed grains within 4 to 5 weeks. The second crop (*ratoon* crop) is thus harvested within nearly less than two months. But the yield is very poor. It is, however, an additional income to the rice farmer, as he obtains this additional grain without any extra care of the crop (*i.e.*, he obtains yields of the two harvests from the same crop.) It is a varietal character. It especially works well with some types of paddy cultivars. For example, a rice variety, *S10.16*, in Andhra Pradesh (Samalkot area) and *Br. 24* in Bihar have been reported to be good rice varieties for a *ratoon* crop. It has also been found that early maturing *japonica* rice varieties, such as *Norin 18*, *Norin 20*, *Sinchu* No. 2 and *Asahi* possess an inherent capacity to *ratoon* quickly after harvest of the first crop (Krishnamurthy *et al*, 1967) and are ready for harvest in the middle of December (*i.e.*, 50 to 60 days after harvesting the main crop). This additional yield from the *ratoon* crop can be further improved with some modification, explained later. Many of the indigenous early maturing rice varieties also possess *ratooning* character and perennating habit, besides some varieties of other maturity group.

In brief under this system, the non-bearing tillers, left over in the stubble, become active. This *ratooning* character of some rice cultivars, such as those mentioned above requires detailed investigations to obtain the maximum production as a second crop of rice from the same planting.

This system of *ratooning* has been improved to give higher production. As far back as 1950's, in Bihar (Sabour), it was observed that if the plot, with left-over stubbles after the harvest is irrigated, followed by light ploughing across once or twice through the stubbles, 20 to 30 percent of the sprouting tillers got separated which exhibit better growth. The crop can also be fertilized for higher production. These operations have to be done within a week after the main rice crop is harvested. After about six to seven weeks, a fairly good rice crop can be harvested. Production is observed to be nearly proportional to the percentage of the sprouted tillers separated *e.g.*, if 30 percent of them are separated from the main stubbles, nearly the same percentage of grain production of the main crop yield, is obtained:

If the main crop yield, say is 3 t/ha, the *ratooned* crop may give an additional yield of nearly one tonne per hectare within the next nearly two months, the total being 4 t/ha. Success will also depend on identifying suitable rice types from within the local varieties preferably.

Such a system can serve as a double cropping system in rice with a single planting. It can be further modified, if the left-over stubbles are separated mechanically by some simple mechanical devices, such as a sharp iron blade attached to a wooden handle, enabling the worker to work with it standing in the rice field, like a walking stick to separate the tillers from stubbles (clonal propagation treatment).

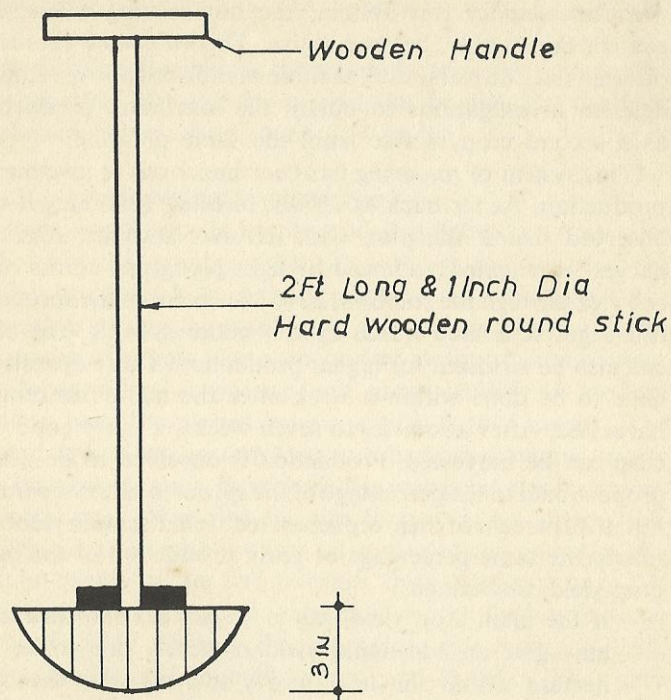


Fig. 9 An implement like a walking stick to separate the tillers from stubbles in the standing field of rice with a little standing water, to harvest a good *ratoon* crop of rice after harvesting the main crop.

The other approach to take advantage of the same plant material was demonstrated by the following experiment. During the month of January, 1963, stubble plants of *GEB. 24*, grown during the *Kharif* season of 1962 were uprooted, separated and replanted. The crop uniformly flowered and gave 20 maunds/acre. This trial was carried out on a farmer's holding which impressed him much, as he did not have

to use any seeds at all for this crop to raise seedlings in a seed-bed.

(4) *beusaning*/*biyasi* system

This system is practised in Orissa, known as *beusaning* and in Chhattisgarh, known as *biyasi*, as it is found very beneficial and economical for broadcast in low rice lands. It serves the purpose of interculture, thinning and weeding.

The system involves broadcast of paddy grains with a higher seed rate (than as required in transplanting) just before the on-set of rains in June in low rice lands, kept ready for sowing. After germination when the crop is a little over five weeks old, with depth of water below the height of seedlings, the fields are ploughed across which causes displacement of rice seedlings (Fig. 10) and at the same time the action of the plough serves the purpose of splitting the tillers by about 10 to 12 percent. Such a system creates irregular gaps which are partly filled up manually by throwing clumps of seedlings in between gaps at random. If this gap filling is systematically done (fig. 11) *i.e.*, filling up of the gap by the separated tillers (designated as modified *beusaning*/*biyasi* system, or *phalai*) instead of the whole plants, the yields obtained are in no way less than what is harvested from a transplanted crop. If this modification is introduced, higher yields can be obtained. In a way the rice farmers have been unknowingly practising clonal propagation practice by about 10 to 12 percent through this age-old *beusaning*/*biyasi* system and balancing the production. This is a specialized practice in which some experienced rice farmers are comparatively very efficient. All what is required is to explain to the farmers of the locality the significance of the modified system so that they take full advantage of clone productivity by splitting the tillers systematically and utilize them in gap filling.

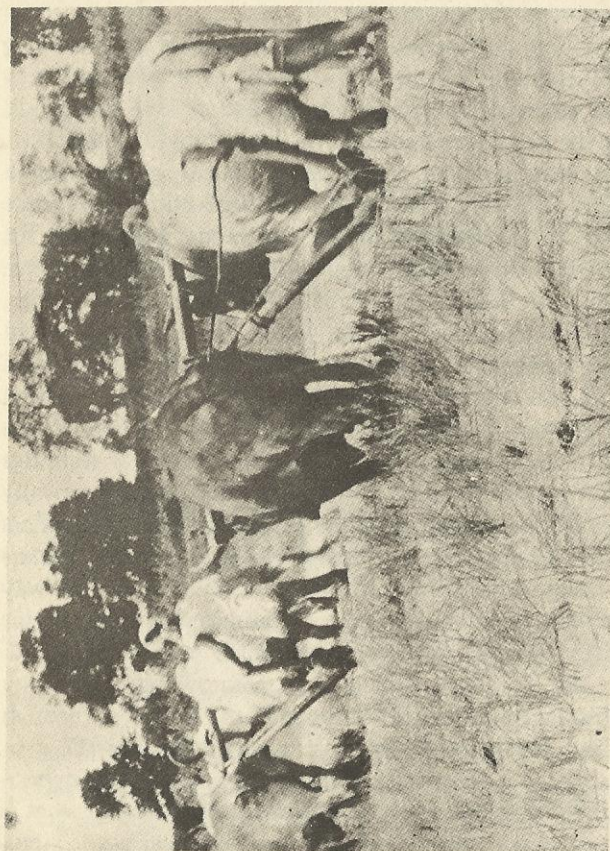


Fig. 10 *beusaning* system of rice culture in Orissa and *biyasi* system in Chhat-tisgarh.

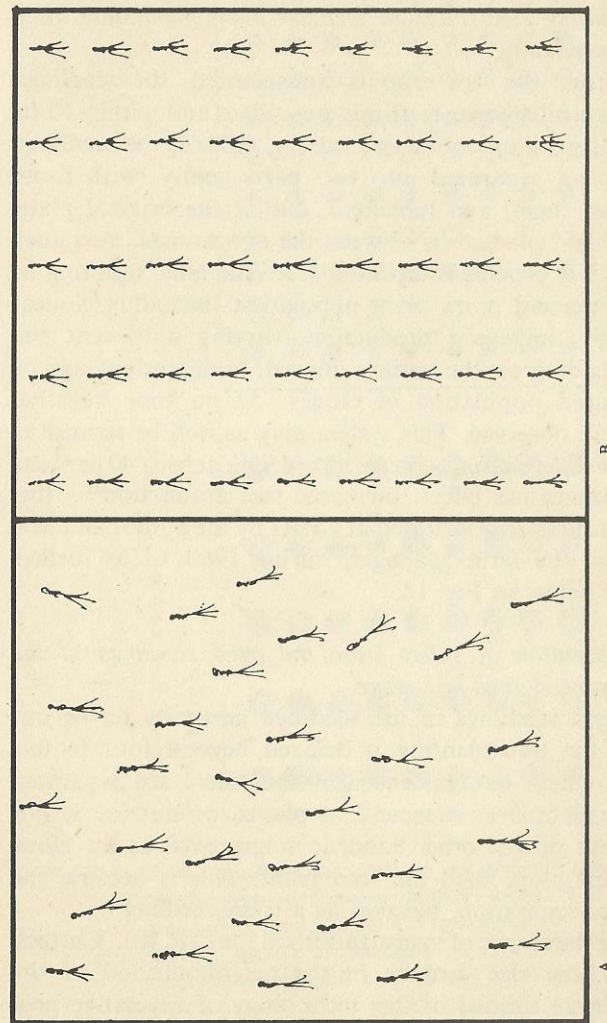


Fig. 11 Systematic gap-filling carried out with separated *tillers* after *beusaning*/*biyasi* system, gaps caused by ploughing.

(A) After *beusaning* by ploughing in rice fields, as seen in Fig. 10.
(B) *beusaning*, followed by gap-filling with clones systematically.

(5) *Splitting rice tillers to increase plant population after transplanting:—*

Soon after the rice crop is transplanted, the seedlings (2-3 at each hill) begin to throw out tillers and within 10 to 12 days, (depending on the rice variety, utilised) the seedlings are uprooted, separated into two parts gently (with roots hanging on them) and replanted, one at the original place and the other, planted in between the two transplanted lines (Fig. 12). The process is repeated at all the hills, resulting in about 40 percent more plant population (including clones) and thereby increased production, varying upto cent per cent, depending on the variety utilised, taking advantage of the increased population of clones. At no time negative results were observed. This system may as well be termed as *modified double planting* system, linked with at least 40 per cent clonal propagation effect. Increased rice production by this system was first demonstrated at CRRI by the author and Mr. M.S. Pillai, the farm Manager, during 1960-61 as further explained below in Fig. 12.

(6) *Separation of tillers from the aged seedlings at the advanced seed-bed stage.*

The aged seedlings in the seed-bed generally throw out tillers, if the transplanting is delayed beyond four to five weeks. In these circumstances, if the tillers are separated and then planted as independent plants, production is not affected but on the other hand, it is improved as the clone plant yields more than the seed plant. This is because the tiller, after separation, behaves as a fresh seedling.

During the course of investigations at the C.R.R.I., Cuttack (1959-67), the rice farmers in the neighbourhood of the Institute were trained in this technology of **vegetative propagation** intensively by holding short training course periodi-

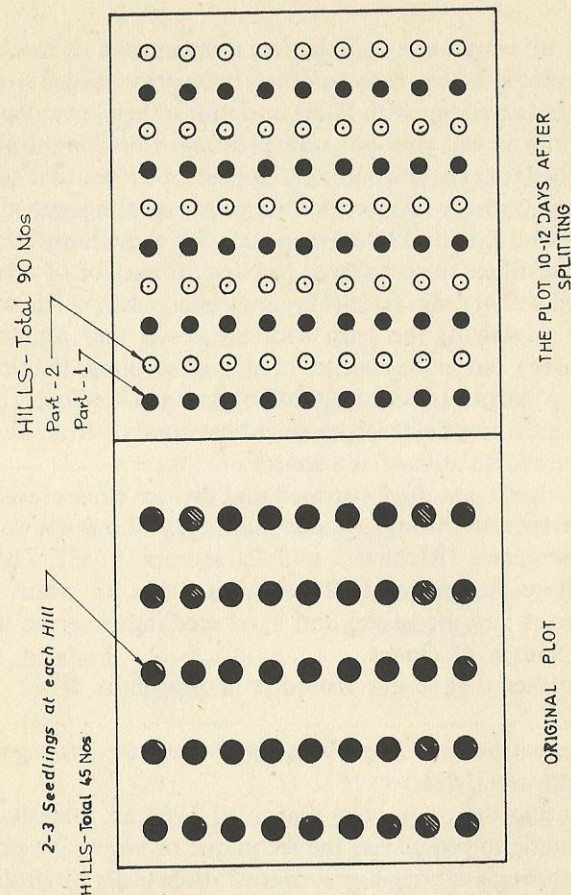


Fig. 12 (1) 2 to 3 seedlings, transplanted at individual hills.
(2) Seedlings grow, throwing out tillers within 10 to 12 days which are uprooted and separated in two parts.
(3) Part I—planted at its original place and Part 2—in between the two transplanted lines. A plot of original 5 transplanted lines with 9 hills (2-3 seedlings), each hill separated after 10-12 days into two i.e., 45 hills increased to 90 hills.

cally. Information available now indicates that it has become a regular practice with some of them (rice farmers) to split the aged seedlings with tillers and utilise them as independent seedlings in carrying out transplanting. For this purpose the seed-beds are not sown thickly *i.e.*, the seed rate at the seed-bed is comparatively low, so that the young seedlings get sufficient space and favourable environment for growth and development of tillers (also referred to later). It may be of interest to record that at times rice fields get submerged due to floods at an early growth of the crop with the result that replanting is necessary, but in the absence of normal seedlings the rice fields remain vacant. In such a situation, the aged seedlings from the unaffected rice fields in the neighbourhood or from any other source can be utilised as a source of clones.

Further it was demonstrated that the rice clones resist water submergence through floods *i.e.*, they show resistance to submergence. (Richharia and Parasuram, 1963). They can, therefore, be utilized in flood prone areas for which special nurseries may be raised and aged seedlings may be utilised, as a source of clones.

Further details are recorded in Appendix III.

Demonstration of technique of vegetative propagation in cultivators' fields

During the main crop season of 1963 an intensive effort was made to popularise the technique of vegetative propagation through twenty-five demonstration trials in 10 different villages of the neighbouring Cuttack Sadar Stage II Block. The yield potential of vegetative propagation technique was tested in four improved varieties *viz.*, GEB.24, J.192, T.141 and T.1242 against a local variety. The results are presented below:—

Response of vegetatively propagated seedlings within the season in increasing the yield—Grain yield in kg/ha.

Variety	No. of experiments conducted.	Normal crop.	Crop from vegetatively propagated seedlings (V.P.)
GEB.24	13	2643	3786
T. 141	10	2626	3451
J. 192	1	3182	4318
T. 1242	1	1482	2963
Local	23	2187	3157

Variety X Method—Grain yield in kg/ha

Method	Variety		Percentage of increase over normal.		
	GEB. 24	T. 141	Mean	GEB. 24	T. 141
Normal	2615	2826	2721	—	—
V.P.	3771	3695	3733	44.2	30.8

Vegetatively propagated crop, in general, has given substantially higher yield than the normally raised crop in all the varieties; thus establishing the superiority of this technique.

During that period it had become a regular practice with some progressive rice farmers in the surrounding locality allowing the seedlings to throw out 2 or 3 tillers by leaving the seedlings a little longer in the seed-bed, followed by

planting the crop with separated tillers simultaneously at planting (atleast from some of the seedlings). The labourers get used to this system with some experience.

In brief the possibilities of applying the technique of clonal propagation in rice in various ways are immense. Unknowingly, the technique already works in the rice culture. Its significance is to be understood and it may be systematically exploited for increased rice productivity, as exemplified here, requiring special attention and treatment wherever it may be possible to apply it. There may be still unexplored phases left, for discovery.

CHAPTER IV TETRAPLOID RICES AND CLONAL PROPAGATION

Induced auto-tetraploid rices invariably have 40-45 per cent sterility which make them unsuitable for growing as normal varieties. But their increased protein content and their possible use for breakfast food hold the prospect for growing them, inspite of their having such draw-backs as spikelet sterility. To increase the single plant yield in such tetraploids, spikelet fertility should be pushed up in particular and other quantitative characters in general by some other means. The technique of clonal propagation which gives 30 to 50 per cent increase and more in yield in diploids was followed in the case of tetraploids also to see as to what extent this spikelet fertility and other yield attributes can be increased.

A comparative study of the seed and stubble planted crops of the diploid rice varieties, *GEB. 24 SR. 26-B*, *Indrasail* and *Seta* and their corresponding tetraploids has shown an increase of spikelet fertility of 16 per cent in *SR. 26 B.* and 11 per cent in *Indrasail*. There was also an increase in the effective ear-bearing tillers in the stubble planted crop. This feature is probably due to the differences in the physiology of the plants, grown under the different methods. It may, therefore, be concluded that clonal propagation may help to increase the spikelet fertility and thereby grain yield in tetraploids, facilitating their growth as a normal crop.

The technique was also demonstrated with some of the tetraploids, on a field scale on a Government Seed Multiplication farm in Orissa during 1963 and 1964.

The utilisation of clustered type of paddy has a special significance under this system, as explained in Chapter VIII.

Their tetraploid forms on which work was initiated in 1963 at CRRI would also prove useful.

The following observations on tetraploid rices, recorded by the authors (Richharia and Govindaswami, 1966, p. 298) are also relevant to draw attention to the importance of tetraploids in rice:

"..... the high percentage of protein, observed in the tetraploid rices upto 13 per cent which can well be comparable to that of wheat, offers, in a way, good scope in the efforts to improve the protein content of the existing normal cultivated rices which have usually 6.5 to 8.7 per cent protein only. Additionally it may be mentioned that the protein of rice is of superior quality in respect of growth promotion."

CHAPTER V

APPLICATION OF CLONAL PROPAGATION TECHNOLOGY FOR HIGH STANDARD OF QUALITY AND AROMATIC RICES WITH SPECIAL REFERENCE TO EXPORT TRADE.

Amongst the export plant industries which India already commands, such as the jute, cashewnut and some medicinal plants *etc.*, quality-aromatic/scented rices enjoy a special position, as they have strong export potential, provided strict quality control is achieved as some of them deserve monopoly export trade. At present it remains confined to *Dehradun Basmati rice variety* only, exported mostly to the middle-east countries, whereas innumerable quality-scented rice types are grown all over the rice belt of the country, enjoying local preferences only including the neighbouring cities being cultivated mostly under organic manuring for quality purposes to fetch higher prices in the market, yet many such aromatic types remain unnoticed and un-recognised, confined to a few rice farmers, especially in tribal areas; for example we have discovered over 300 such quality-aromatic types in the tribal areas of Chhattisgarh in Madhya Pradesh, besides the already well-known such quality-types as *Chinnor*, *Badshabog*, *Dubraj*, *Kalimuchh* and *Chhatri*. Such types as *Bishnubhog*, *Shrikamal*, *Kubrimohar*, *Dilbaksa*., *Loktimachhi*, *Tulsi Amrut etc.* remain confined to limited surrounding areas mostly inhabited by tribals. Similar quality types exist in other States also, such as *Ramduni* and *Katarni bhog* (West Bengal), *Ambemohar* (Maharashtra) and *Tulsi-manjari* (Bihar) *etc.* Such quality-rices, if projected, would command better acceptance because of their superior quality rice (superfine scented grain) with high nutritive value, both for internal consumption and export trade. But for all such

purposes quality control is essential. This can now be carried out easily, if the first grade seed is produced by practising the clonal technology utilising typical individual aromatic grains and multiplied through clones. The method not only ensures quality of a rice variety but it allows the production of quality hybrid rices to produce more per unit area, by utilising the eco-types of individual scented types in the hybridization programme. As it is, due to intensive inbreeding, the productivity in quality-rices, in general, has gone down considerably and clonal propagation technology is the only direct approach to improve this specialised plant industry. Further more essential and immediate steps to be taken is to collect and maintain this rich rice germplasm which is fast disappearing. The subject is further discussed under chapter VI (Item 8)

There are other aspects of this technology in relation to quality-aromatic rices, *e.g.*, aroma works as dominant or partially dominant, being controlled by 1-3 dominant genes.

The F_1 grains (F_1 plant, raised from the crossed seed being multiplied clonally to any limit) can be marketed and thus a strict scientific quality control can be maintained, besides productivity (Fig. 13). The selected parents (donors: for aroma and productivity) may be maintained at a Central place. This is entirely a new approach to develop a new plant industry, based on quality-aromatic rices with high-yielding potentials, including hybrid vigour to be grown under organic manuring. Such endeavours can be undertaken by the existing seed organisations, such as the State and National seed Corporations food Corporation of India Cooperative Societies and enlightened rice growers. Exploitation of quality hybrid rices as explained above deserves attention as a practical commercial proposition.

In brief the clonal propagation technology can prove very

useful to ensure increased production of high standard quality-rices of desired types for both internal market and export trade. Thus remunerative prices can be offered to the rice farmers in the tribal areas as well. The tribal farmers possess inherent capacity and superintellect to manage rice culture efficiently in their environments.

INCREASED PRODUCTION OF QUALITY AROMATIC RICES

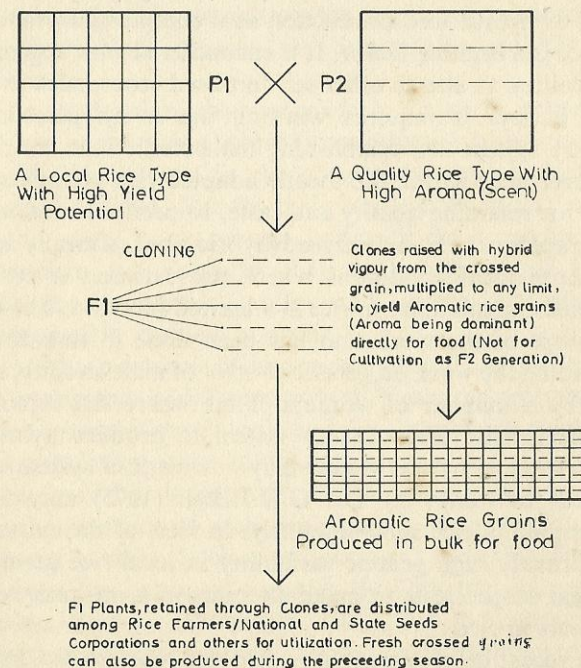


Fig. 13 Application of clonal propagation technology in relation to aroma in rice.

CHAPTER VI CLONAL PROPAGATION AND EXPLOITATION OF HYBRID VIGOUR IN RICE — THE INDIAN HYBRID RICES

It is well known that the F_1 cross-combinations, involving rice crosses, show hybrid vigour, such as increased number of ear-bearing tillers, height, number of spikelets *etc.*, and ultimately grain and straw yield. But being a self-fertilized crop, it has not been found possible to exploit this phenomenon, as hybrid seed production as a commercial proposition in rice is a limiting factor. It is encountered with a number of difficulties, as also in other self-fertilised crops, such as wheat and barley. It requires working out a *cytoplasmic male-sterility system i.e.*, establishing male-sterile lines and pollen restorer lines within the locally adapted rice germplasm and also for retaining quality and taste, to produce economically and rapidly, the F_1 hybrid seed (hybrid rice), naturally adapted to those local conditions where rice farming is practised, as wider adaptability in rice is a limited function. The author is aware of the work that has been done in this direction, including the work on genetic control of male sterility, carried out by a number of workers. Thus where the exploitation of the genetic male-sterility system to produce hybrids for expression of hybrid vigour may not work, a system as suggested for barley by Dr. G.D.H. Bell (1975) may also be attempted in rice simultaneously. In view of the existence of abnormally high genetic variability in local rice germplasm, a great scope exists to make attempts in some such research projects in rice.

A recent development in hybrid rice research in China and the IRRI (Philippines) has been reported by Virmani *et al* (1981) that commercial exploitation of heterosis in rice has

been found possible by the use of cytoplasmic—genetic male sterility and fertility restoration system and a number of cytotsterile maintainer and restorer lines in rice are available in China and IRRI. These achievements encouraged the ICAR to undertake such projects at a number of rice research centres in India in recent years by introducing fresh rice cultures for male sterility from China and IRRI. So far results of practical value have not been known; moreover, a major risk of introducing new genes about which the least is known, into the Indian rice culture through such exotic material always exists. In this connection the latest observations on hybrid rice research recorded by Swaminathan (1985) are also relevant:

“The spectacular advances made in China in introducing and popularising hybrid rice production have aroused world-wide interest in the commercial exploitation of heterosis in rice. But the male sterile lines identified in China show poor growth under tropical conditions. Therefore it is necessary that stable male sterile lines with good combining ability and restorer systems be developed in tropical countries”.

Due to the existence of enormous genetic variability in the rice germplasm in different parts of India, the probability of the occurrence of male sterile and semi-sterile rice plants in the bulk population under cultivation is high. Their spontaneous appearance too is not rare. An intensive survey would disclose the presence of such rice plants in every traditional rice growing locality. Such a situation was met with during the course of our botanical survey in the Chhattisgarh region of Madhya Pradesh (Richharia, 1979), but little attention was paid then to preserve them. Some rice cultivars regularly threw out such sterile and semi-sterile plants. Some tribal rice farmers have their own methods to identify such rice

cultivars, beyond our understanding and they practise their own conventional methods in introducing vitality in their rice culture. We now know that once such male sterile plants are discovered, they can be maintained by clonal technology and multiplied at will to any extent for utilization in the hybrid rice research programmes, explained later.

Other approaches to exploit hybrid vigour in rice.

As explained above, such an approach (exploitation of male sterility) requires some technical problems to be solved, utilising exclusively the adapted rice material of local origin (location—specific) and being also comparatively very time consuming and long range, characteristic of self-fertilised crops. The author and his associates, therefore, simultaneously worked and suggested other alternative approaches for immediate application (Richharia, 1960, 62; 63; Richharia and Misro, 1960 *etc.*) as briefly described below:

The following eight major approaches are suggested to develop *Indian Hybrid rices* and their possible utilization to increase rice production per unit area:—

- (1) use of clonal propagation technology to exploit heterosis at F_1 stage through clone plants and to exploit heterosis at F_2 stage through normal seed plants (by multiplying the F_1 plants vegetatively).
- (2) Floral modification and out-crossing, to produce crossed seeds (hybrid rice) commercially.
- (3) Natural crossing in varietal composites: working out out-crossing in varietal composites to identify compatible combination for higher rice yields, to take advantage of natural crossing even between different groups of rice cultivars.
- (4) Use of back-cross technique to utilize semi-sterile rice hybrids with compatible rice varieties, the former being multiplied vegetatively.

- (5) Utilization of marker genes, easily identified at transplanting (seedling stage) in segregating F_2 population (F_1 plant, multiplied vegetatively (See item 3 of Chapter II).
- (6) Cytoplasmic inheritance for high fertilization responsiveness and vegetative propagation.
- (7) Multiplication of indigenous male sterile plants by clonal technology to any extent, utilised for hybrid rice production commercially with compatible and desired pollen restorer culture.

- (8) Rejuvenation of rice culture in general, tract-wise.

(1) One method of taking advantage of the expression of hybrid vigour is to multiply the F_1 plants vegetatively and collect seeds for F_2 population to exploit hybrid vigour, although a little lesser than that in F_1 generation. A great advantage associated with this procedure is that (i) It is well within the reach of the rice farmers themselves, (ii) Inbred rice cultivars can be made vigorous by crossing the eco-types within individual varieties and (iii) The individual F_1 plants can be propagated to any limit as illustrated in Fig. 14, taking crossed seedlings as an illustration.

(a) Soon after the matured crossed seed is obtained and put for germination, followed by splitting at a regular interval (15 to 20 days) *e.g.*, when the crossed grain is harvested during November—December, after a resting period of say one or two months, it can be put for germination in the 1st week of February when the atmospheric temperature begins to rise. By the end of July when the normal transplanting is carried out there will be about 8 (n) splits and if, on the average, only 3 tillers (x) are separated every time, the total number of clones would be $x \cdot n (3^8) = 6561$ clones which produce grains for F_2 population, grown by the normal method in the rice field. The whole concept is to exploit hybrid vigour in F_2

stage through seed plants, for which the seeds are multiplied with F_1 clone plants. To illustrate it further during 1961 different cross combinations were tested at C.R.R.I. cuttack involving a number of improved varieties together with their hybrids in F_1 and F_2 generations in order to obtain more information on the utility of this practice.

In six cross-combinations, it has been found that a sufficiently good crop could be obtained from F_1 plants, multiplied vegetatively as recorded below.

F_1 Plants of Different Cross-Combinations of Rice Varieties, multiplied vegetatively and finally planted during the main season of 1961.

Cross-combination F_1	Total No. of plants at final planting (12 in. $\times$ 6 in.)	Area occupied (acres)
W. 114 $\times$ GEB. 24	36,657	0.42
GEB. 24 $\times$ G.S. 137	25,520	0.29
PTB. 10 $\times$ W. 112	2,532	0.03
CH. 45 $\times$ W. 135	17,888	0.20
W. 140 $\times$ ϕ . 412	01,080	0.70
JRS. 120 $\times$ T. 141	17,482	0.20

To test the effectiveness of this technique at the F_2 generation, stubbles of eleven F_2 plants were propagated vegetatively from a cross between *J.192* (a selection from a fine-grained variety of Orissa) and *GEB. 24* (a popular variety of Madras).

The fourth tiller-separation stage was the final planting of the clones as a field crop in the main season and the results are presented in the Table below.

Vegetative multiplication of F_2 plants and parents from cross, J. 192 $\times$ GEB 24, Carried out during 1961.

Material	No. of tillers first planting.	No. of tillers second planting.	No. of tillers third planting.	No. of tillers fourth planting. (final planting 12 in. $\times$ 9 in.)	Area occupied (acre)
J. 192 (Parent)	15	76	430	6,703	0.12
GEB 24 (Parent)	27	81	325	3,433	0.06
F_2 plants					
1	18	123	040	10,020	0.17
2	14	87	675	9,440	0.16
3	15	202	1,832	22,832	0.39
4	17	157	1,425	13,480	0.23
5	20	113	800	8,738	0.15
6	15	142	1,366	13,250	0.23
7	15	167	1,318	13,140	0.23
8	13	48	869	5,026	0.09
9	23	109	1,050	9,848	0.17
10	16	88	950	7,655	0.13
11	24	148	1,350	7,740	0.13

Considerable variability was observed in the individual F_2 populations in respect of multiplication of plants (tillering potential) and all the F_2 plants had shown higher production capacity except one (No. 8), as compared with the parents. These observations indicate the possibility of exploitation of hybrid vigour at the F_2 stage as well (through clones) with

an added advantage that F_2 plants with desirable recombinations can be picked up. (Richharia, 1962).

In another experiment, conducted during 1963, stubbles of the crosses *JBS 674* $\times$ *Changsan* and *Ac.2925* $\times$ *Changsan* were multiplied and grown along with the parental seedlings in two replications. An increased yield of 16.1% in the first and 16.4% in the second instance was obtained.

In another series the following observations were recorded.

Yield in kg/ha.

Treatments	Yield	% of control	Remarks
1. GEB. 24 Normal	2514	100.0	The hybrid, vigour present in the F_1 generation of the cross especially under the influence of veg. propagation has been responsible to give an increased yield of 87.9% over one of the parents, GEB. 24.
2. W. 114 Normal	2171	85.4	
3. W. 114 $\times$ GEB. 24 (F_1) vegetatively propagated.	4775	187.9	

The stubbles left over in the field from F_1 plants can also be utilised during the next season for raising F_2 seeds for general cultivation. In this case even one stubble, as stated earlier after 13 splits (every time three clones, splitted) is enough to produce 15, 94, 323 clones to cover 34.17 hectares of transplanted area, clone to clone distance being 15 cm $\times$ 10 cm. This would yield at the rate of 4000 kg. per hectare nearly 1360 quintals of grains. This may cover an area of about

2720 hectares of transplanted normal seedlings (F_2 population) exploiting hybrid vigour in the second year to obtain at least 50 per cent increased yield, as illustrated in Figure 14.

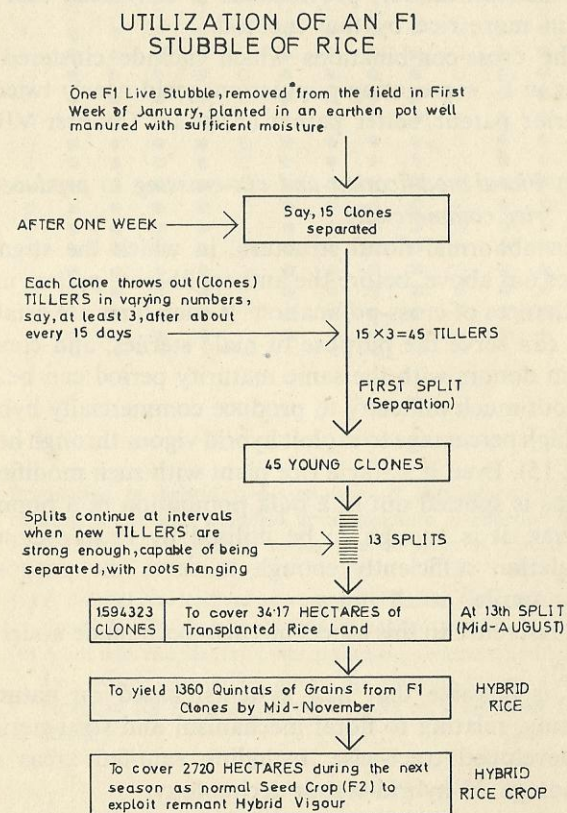


Fig. 14. Different stages to depict the production of hybrid rice.

The F_1 stubbles can also be distributed among the growers who may themselves prepare hybrid rice seeds for the next season. It is known that a rice farmer in the traditional rice area does not mind to practise any field technique, requiring hard manual labour, provided he is convinced that he can obtain more rice by that method.

The cross-combinations which include clustered paddy types in F_2 segregating population, yield nearly twice of the superior parent/better parent (Also see Chapter VIII).

(2) *Floral modification and out-crossing to produce hybrid rice commercially.*

An abnormal floral structure, in which the stigma protrudes out above, before the anthers liberate pollen, increases the chances of cross-pollination. If such lines are established, they can serve the purpose of male steriles, and compatible pollen donors with the same maturity period can be located without much difficulty to produce commercially hybrid rice at a high percentage to exploit hybrid vigour through heterosis, (Fig. 15). Even if a single rice plant with such modified floral organs is spotted out in a bulk population of a popular rice cultivar, it is enough to be utilised by raising clonally its population sufficiently enough to serve the purpose of a 'male sterile' at all times.

A reference to this aspect has also been made under item 3, below.

It is possible that new systems, based on natural out-crossing, relating to floral mechanism and semi-sterility can be developed tract-wise, including rain-fed areas to take advantage of hybrid-vigour technology.

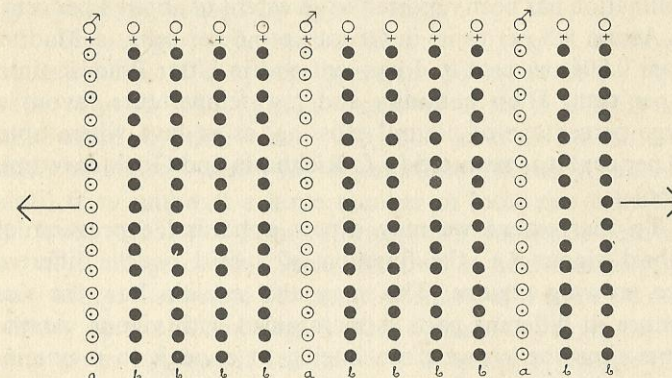


Fig. 15 Production of hybrid rice commercially throughout—crossing between a line with modified floral structure to function as 'male sterile' with a compatible normal line to serve as 'pollen donor'.

- (a) A normal rice cultivar as a source of pollen to serve as a pollen donor. Preferably it has to be a little taller than (b).
- (b) A line with rice plants/clones, possessing abnormal floral structure i.e., Stigma protruding above the stamens before it becomes receptive for self-pollination, to serve as a substitute for male sterility.

(3) *Natural Crossing in varietal composites*

It is of interest to observe that a variable percentage of cross-pollination between rice varieties also takes place, though self-pollination is a rule in rice. In Bengal natural pollination has been reported to an extent of about 4 per cent. In Assam 0.5 per cent; in Orissa upto 6 per cent, in Madras from 0.004 per cent to 7 per cent and in Uttar Pradesh upto 2 per cent. High humidity and low temperature favour a large percentage of natural crossing, as in Java where upto 20 per cent was reported (*c.f.*, Richharia and Govindaswami, 1966).

To that extent we may expect a natural expression of hybrid vigour *i.e.*, the function of hybrid rice in different rice growing regions. This may also explain how the rice culture in different parts is maintained with vigour. At the same time the growers are intelligent enough to maintain, purity of their rice cultivars fairly well, by picking up ear-heads of their varieties at the time of harvesting, representing their individual types for cultivation during the next season, based on their knowledge and experience, accumulated and descended down for generations. At times even the pure rice varieties show pollen sterility in certain percentages which may be utilised to produce hybrid seeds to that extent, involving compatible cultivars particularly their eco-types *e.g.* at the Rice Research Station, Bhubaneswar (Orissa) the following sterility percentages were observed in the three local types.

FR 43 B : 9.0

SR 26 B : 12.1

AC 1951 : 14.7

Environmental factors which cause such sterility in pure varieties have to be worked out and utilised to our advantage.

Under this system nearly 750 quintals of quality seeds of hybrid rice were produced by the natural hybridization process

with compatible cultivars (eco-types of a main variety), mixed with the quality seed of the main type. The compatible cultivars are so selected that there exists little variation in grain quality and maturity period and at the same time deriving advantage, caused by hybrid vigour.

In Chhattisgarh, the traditional area of rice in Madhya Pradesh, there is a system prevalent to broad-cast a few grains of paddy of a particular cultivar in the rice fields recommended by the tribals' religious head (Head Priest) which he himself selects (by a procedure difficult to understand) from amongst a large number of local rice cultivars which the tribal rice farmers bring on a particular festival day at a village centre. Such a festival is held annually in every village just before the commencement of the rice season in many parts of Chhattisgarh. This system is now gradually being given up, but it still persists in many typical tribal villages. We were very anxious to know more about this system which would naturally encourage mixture in the local varieties, but our collections of the local cultivars have demonstrated that the rice types collected from those localities where this system was prevalent were of good standard (not complex mixtures). With some difficulty we could obtain some grains of such types, selected by the Head Priest and studied them, but we were surprised to observe that hardly we could collect seeds from those types (which were grown in a net house). It was found that, they were either partial male sterile plants (about 40 per cent) or plants with some sort of abnormal floral structures (about 60%). Further investigations could not be continued. This system requires detailed studies, as in our collection of over 17,000 cultivars, certain percentage of them did show sterility, partial sterility and segregating populations (representing natural crossing). Again it is not uncommon to observe half-chaffy grained rice culti-

vars being grown along with normal types by the rice farmers, especially in the tribal areas. Such a situation deserves thorough checking up and the findings to be utilized. It must be realised that our knowledge of the rice plant under cultivation in different parts under natural surrounding is not adequate. We know so little about it, whereas so much remains embedded with the rice farmers in the traditional areas. In the wake of dwarf and semi-dwarf HYV technology we are neglecting what is already known. So much knowledge of rice accumulated for centuries and being descended down has already been lost and still being lost fast whatever is left by neglecting it.

A special peculiarity exists in some areas where rice farmers always grow certain rice cultivars on their farms, besides other types. In such types, out-crossing has been observed to be very high, such types are also exchanged between the neighbour farmers. A regular system of planting certain rice types in alternate years, also prevails, meaning a rotation practice, involving some specific rice types, as if they function as leguminous substitutes. It seems traditionally a system has been developed to take advantage of 'hybrid vigour' from outcrossing, *a system which is easier to increase production*. This also explains why the number of cultivars in rice is kept high on individual rice farms. It is, therefore, evident that the existing system, pertaining to the rice culture in any locality in a traditional area need not be disturbed or replaced unless it is proved that replacement is beneficial. In terms of our modern knowledge every system, evolved in the past has a meaning and is based on a sound scientific principle, probably developed by 'trial and error' methods and has descended down for centuries.

Another practice which is commonly followed in the traditional rice areas is the growing of *varietal mixtures* which leads to out-crossing to a great extent, between plants

of different varieties to produce 'hybrid rice' effect in the subsequent crop. Keeping a number of rice cultivars on the same thrashing floor after harvest also referred to earlier, so commonly practised leads to such a situation. It is a general belief that a rice farmer is considered fortunate if he grows more number of varieties.

In Madras a system exists where a late maturing rice variety is grown mixed with a short-duration variety, e.g., *Adt 6* and *Adt. 7* of 220 days duration are mixed with a short duration type. It has also been suggested by the author to grow mixtures of non-lodging/stiff-strawed types with lodging high yielding types to prevent the rice crop from absolute lodging. If a suitable combination is worked out, it may be possible to combine both the objectives of preventing the rice crop from lodging and producing hybrid seeds by chance cross-pollination to exploit hybrid vigour. At the adaptive rice Research centre, Baronda (Raipur, M.P.) 27 Varietal Composites, mainly based on hull colour and grain quality (Coarse, medium and fine), irrespective of maturity period, were prepared from a collection of about 5,000 rice cultivars. On comparison such composites proved higher yielders than their corresponding normal cultivars harvesting being carried out at one time when the last maturing plants were ready for harvest (shedding being the least in the early and medium maturing plants). In such composites, the expression of higher grain yield in the later generation is caused mostly by hybrid vigour induced by out-crossing between different types, producing hybrid rice.

4. Use of Back-crosses/hybrid sterility and clonal propagation.

A considerable variation in hybrid sterility has been observed by different workers in the intervarietal, inter-

subspecific crosses, involving *indica*, *japonica* and *Javanica* of *Oryza sativa* as well as interspecific *O. sativa* and *O. glaberrima* crosses, involving the cultivated rices. This also includes pollen sterility in the hybrids. Such a situation can be utilized to produce hybrid seeds from suitable combinations by working out experimentally spikelet fertility, caused by natural out-crossing on the male sterile F_1 plants from the normal parents or other useful inbred lines and utilised. The crossed grains (spike-lets) can thus be produced in abundance by multiplying clones and utilising them by planting them in lines alternating with and close to the lines of normal parents or other useful inbreds, serving as a source of fertile pollen, and to work out the increased production including that in the following generation, caused by the phenomenon of hybrid vigour in desired cross combination. This has to be worked out with the locally grown indigeneous rice cultivars. The production of clones of pollen-sterile F_1 hybrid is guaranteed in any number by vegetative propagation technology and the source of pollen lines is a matter of choice particularly in relation to the inter-varietal cross-combination. In brief, therefore, compatibility of ovules of F_1 (with pollen sterility) with other normal lines as a source of normal pollen is the crux of the solution. To work out such combinations is simpler to understand even by field workers and rice farmers than to understand the use of cytoplasmic-genetic male sterility and fertility restoration system, proposed and followed by Virmani *et al* 1981, also referred to, elsewhere. This line of Indian Hybrid rice research, if pursued vigorously, will remove the bottle neck of producing crossed seeds by this system, utilizing clones of F_1 male sterile rice plants.

[In fact 'a male sterile' once obtained from any source can be maintained through clones and multiplied to any limit and utilized with compatible pollen donors for producing

hybrid rices commercially, as also discussed elsewhere. (Fig. 16)]

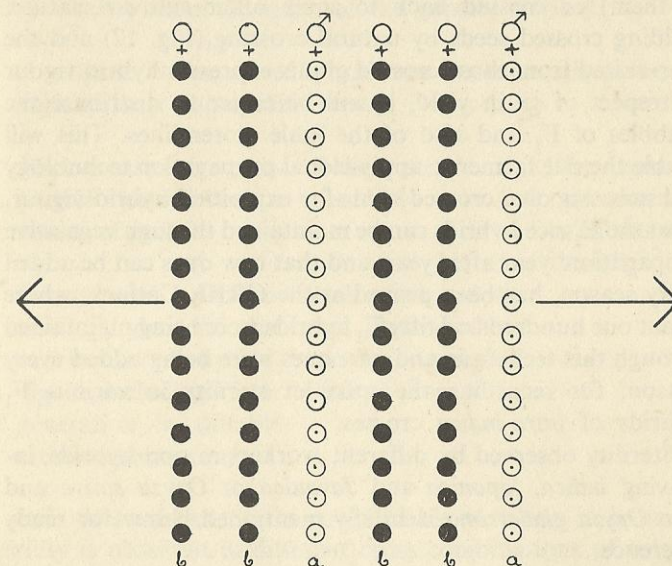


Fig. 16 Production of hybrid rices commercially utilising a male sterile, propagated clonally with a compatible pollen storer cultivar.

- (a) Self-pollinating rice cultivar (compatible line) serving as a pollen donor.
- (b) A male Sterile line of clones, multiplied vegetatively: Two lines alternating with (a): Once a male sterile plant is located, it can be maintained through clones by the rice farmers themselves. All other cumbersome processes are dispensed with.

A great advantage associated with this system is that once it is known that a particular cross-combination (F_1) with sterile pollen back-crossed to one of the parents (or both of them) or crossed back to some other cultivar culture, yielding crossed seeds by natural crossing (Fig. 17) and the crop raised from those crossed grains expresses hybrid vigour in respect of grain yield, it will be easier to distribute the stubbles of F_1 and also of the male storer lines. This will enable the rice farmer to apply clonal propagation technology and raise his own crossed seeds for exploiting hybrid vigour. That the F_1 rice hybrids can be maintained through vegetative propagation, year after year, and that new ones can be added every season, has been proved at the CRRI, Cuttack, where about one hundred and fifty F_1 hybrids were being maintained through this technique and new ones were being added every season, for recording the spikelet sterility in various F_1 hybrids of *intra-indica* crosses.

Sterility observed by different workers in rice hybrids involving *indica*, *japonica* and *Javanica* or *Oryza sativa* and also *Oryza glaberrima* is briefly mentioned below for ready reference.

Cross combinations of F_1 Hybrids of rice.	Variation observed in the degree of spikelet sterility (In percentage).	Variation observed in Pollen sterility (In percentage).
1. Indica $\times$ Japonica	16 to 97	7 to 93
2. Javanica $\times$ Indica	8 to 82	—
3. Japonica $\times$ Javanica	29 to 98	—
4. Indica $\times$ Indica	0 to 100	—
5. Javanica $\times$ Javanica	54	—
6. Japonica $\times$ Japonica	Trend not different from what observed under (4) & (5) (Data not available).	—
7. <i>O. sativa</i> $\times$ <i>O. glaberrima</i>	Not available	25-100

1. Sterility as estimated from the seed counts in the panicles is a result of both genetic and environmental causes.
2. The measure of sterility occurring in the pollen grains is a fairly accurate index of the genetic sterility.

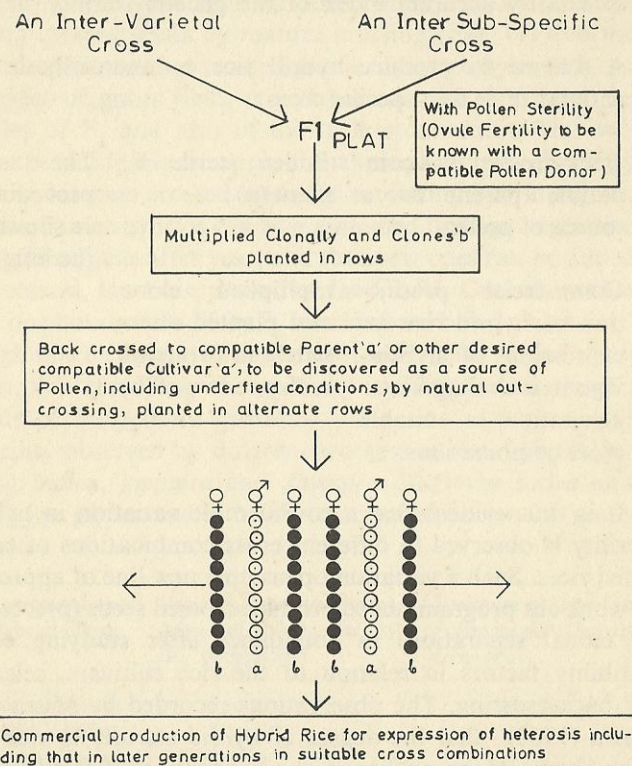
A scheme to produce hybrid rice commercially (Inter-varietal/Inter Sub-specific cross)

- a. Back-crossed to a compatible parent as a source of pollen
 - b. Pollen sterile F_1 plant (a)
- The same procedure, as shown at the left.

Commercial production of hybrid rice for expression of hybrid vigour, including a later generation in suitable cross combinations. multiplied clone and planted alternately in two rows with one row of (b)

It is thus evident that a considerable variation in hybrid sterility is observed in different cross combinations of cultivated rices. Such a variation opens up a new line of approach to work out programmes to produce crossed seeds (preceded by clonal separation) in abundance after studying compatibility factors in relation to the rice cultivars, selected for back-crossing. The observations recorded by Misra and Misra (1960) "that the degree of hybrid sterility in rice has been shown to be no bar in the production of fertile combinations, no matter how high the spikelet sterility may be," and the conclusions drawn by Richharia *et al* (1962) that "The preservation of the characteristic features of different sub-species may, therefore, be due to their extremely close adaptation to the temperature, day length and other climatic

A POSSIBLE SCHEME TO PRODUCE HYBRID RICE COMMERCIALY UTILISING INTER-VARIETAL/INTER SUB-SPECIFIC CROSSES



The success demands intensive field experimentation and genius of Rice Breeders

Fig. 17 Pollen sterile or semi-sterile back-cross hybrid plant, multiplied clonally to serve as a male sterile, out-crossed with a compatible rice cultivar.

and edaphic conditions in the different regions," are indications of the strong probability that non-genetic/environmental factors also count greatly in rice in a different measure, not properly understood. It is, therefore, logical to conclude that production of hybrid seeds may also be, to some extent, a sort of manipulation. At times, "trial and error" approach in the experimentation may have to be resorted to.

A possibility to grow and produce rice hybrid seeds in the second crop season and utilise them during the following main crop season to exploit hybrid vigour and obtain higher production needs intensive planning and experimentation. This may be done within a region or even distant localities may be involved e.g., Andhra Pradesh can produce hybrid seeds during the second crop season (December-April) to be utilised in Madhya Pradesh to raise hybrid rice crop during the first (main) crop season (June-December) provided dormancy period is not involved. India's variable environments can be usefully harnessed to take advantage to produce hybrid seeds and take advantage of good expression of hybrid vigour. Some minor variation is to be made even in adapting the new technology, depending on the prevailing environments.

It is also observed that even pure varieties, showing pollen sterility when grown in some new locality, can be used to produce hybrid seeds. The cause of male sterility may be attributed even to some external environmental factors in which circumstance, the female fertility may be expected to produce hybrid seed by discovering compatible male parents (pollen restorers) Seshu and Dubey (1967) c.f. Richharia, (1967). Balakrishna Rao (1967) also records variable sterility percentages in pure varieties (*japonica*, *indica* and Taiwan types) when grown during the second crop season (March-July) (summer months) (See Table XV of the original paper, reproduced here for ready reference). The range of percentage

of seed setting in 52 different cross combinations involving intra and inter-racial combinations studied by Balkrishna Rao (1962), ranging from 11 to 100 percent has a direct bearing on this subject of the practical side of producing crossed seeds, involving compatible parents, for exploiting hybrid vigour in conjunction with the modified "hot air emasculation technique." In fact one of the objectives of this line of work was to recognise and isolate such compatible parents which would easily produce crossed seeds for F_1 generation by some such emasculation method and discover a practical means of taking advantage of increased production through heterosis, to dispense with the use of cytoplasmic male sterile lines.

For example in a $j \times i$ cross, *Hakambri* $\times$ *N 22*, 100 per cent seed setting was observed and if 'hot air' mass emasculation technique is applied, followed by dusting pollen grains from ripe anthers, 100 per cent crossed seeds for F_1 plants could be obtained and the effect of heterosis may be judged. A simple mechanical device in the form of a hot air jet blower-cum-pollen receptacle attached to another jet blower, would serve the purpose.

For emasculation and pollination the following method was also found effective from the experience gained at Faizabad by Balakrishna Rao (1967): P. 275.

"Anthesis takes place between 9 A.M. and 11 A.M. depending on varieties and on weather conditions. Successful emasculation and pollination was carried out with maximum setting of 100% with average setting of 38.6% under the field conditions. Forceps and hot water methods were tried without much success; the method to allow the spikelets to open naturally and quickly remove the anthers before they burst open met with good success. For successful emasculation in this

way, main or primary tillers are found to be suitable and forcing the pace of opening with forceps when lemma and palea first start opening. Exposure of panicles to hot air for 2 to 4 minutes to induce premature opening of spikelets was also tried. This had forced spikelets to open one or two hours before they actually open without damage to panicles. For pollination, dusting pollen grains from anthers collected earlier gave poor setting, dusting with ripe anthers is found to be correct procedure."

In brief mass emasculation techniques to produce crossed seeds as suggested by different workers require intensive efforts to perfect those procedures to produce hybrid seeds, e.g., (1) hot air method (*c.f.*, Richharia, 1966 P. 9) hot air technique, involving dusting with fresh ripe anthers (Balakrishna Rao, 1967), hot water method (Butany, 1961) and a modified technique for emasculation, involving a hollow bamboo tube (Govindaswami, 1961).

TABLE XV (reproduced)

Data on flowering duration and other characters of japonica,
Taiwan and indica varieties in the second crop

Name of the variety	Source	Date of flowering	Fl duration in days	Ht. in cms.	T.T.	EBT	Panicle length	Sterility %
Taichung 65	Taiwan	30-7-63	130	97.5	6.0	5.0	16.9	24.4
W. 1001	"	30-7-63	130	106.6	4.1	3.5	18.6	39.96
W. 999	"	29-6-63	98	107.6	17.1	7.4	15.4	52.5
W. 996	"	6-8-63	136	99.9	7.9	5.8	15.9	58.2
W. 995	"	20-8-63	150	96.3	5.5	5.4	17.2	33.5
W. 1000	"	8-10-63	199	Flowered after short day period only				
W. 1097	"	4-10-63	195					
Hsinchu-50	"	25-6-63	84	116.9	14.4	5.6	16.1	78.0
Aikoku	Japan	6-8-63	136	104.2	5.4	5.0	17.5	52.8
Kameji	"	16-8-63	146	118.1	5.3	5.2	19.6	33.4
Norin. 17	"	28-6-63	97	88.6	7.6	5.0	16.0	48.8
Norin. 1	"	25-6-63	94	55.4	10.7	8.7	10.5	44.8
Norin. 20	"	8-8-63	138	101.7	7.7	5.6	16.5	63.6
Gimbozu	"	25-6-63	94	89.6	6.8	4.9	15.7	39.0
Sinchu No. 2	"	20-8-63	150	110.3	5.6	5.2	17.9	30.1
Zuiho	"	16-8-63	146	101.9	7.1	6.5	19.4	16.0
omachi	"	18-8-63	148	114.8	5.9	5.2	19.5	23.4
Norin 18	"	18-8-63	148	106.4	6.6	6.0	18.5	25.4
Asahi	"	18-8-63	148	94.2	7.4	6.4	17.2	28.4
Norin. 8	"	18-8-63	148	106.1	5.4	5.1	18.7	19.7
Bikuu. 132	"	8-7-63	107	91.22	6.3	4.8	16.7	65.7
Sudha	U.P.	6-7-63	105	117.7	13.7	7.0	16.2	26.5
N. 22	U.P.	4-7-68	103	116.9	15.0	6.0	16.0	23.6
PTB. 10	Madras	26-8-63	156	145.7	12.6	12.1	24.8	14.1

(5) Utilisation of marker genes, easily identified at transplanting (seedling stage) in segregating F_2 population (F_1 plant, multiplied vegetatively to yield seeds for F_2 population).

Rice farmers, particularly in hilly tracts, maintain a large number of rice varieties with purple leaf-blades which are utilized to irradicate wild rices from their rice fields, as the latter with green leaved plants are easily distinguished from the former with coloured leaf-blades at the seedling stage. In an experiment conducted by the author during 1962 and 1963 at Cuttack, the F_1 plant of the cross, *JBS.120* (purple) $\times$ *T. 141* (green) was vegetatively propagated and a large population of F_2 seedlings, raised which were grouped in two separate lots viz., (1) green and (2) purple seedlings, and transplanted separately in adjacent plots. The green plants recorded 3666 kg/ha (3273 lb./ac), whereas the purple plants yielded 900 kg/ha (804 lb./ac). The mixed population gave 3250 kg/ha (2900 lb./ac).

Ordinarily purple varieties are low yielders, but they would be capable of generating heterosis in combination with green varieties as well, as recorded above. If more purple varieties are involved, varietal response may be exhibited. Such a line of investigation deserves attention, as the method to multiply F_1 plants is at hand, the purple and green (F_2) seedlings being separated easily at the transplanting stage. It may be of interest to record that 1-3 dominant genes control the expression of purple leaf-blade. It has, however, been observed by some workers that the existence of inhibitory gene suppresses the expression of the gene for pigmentation (leading to green leaf-blade), which otherwise is dominant (Misro *et al*, 1960).

The experiment recorded above serves only as an example to indicate that some gene markers, coupled with their linkage

relationship with yield contributing characters, can be utilised for increasing rice production.

It seems, such purple types were being utilised in the past in many other ways which still remain to be rediscovered. Purple rice varieties can be located practically all over the rice regions, if a thorough search is made in the country. A survey, carried out, in Madhya Pradesh disclosed the presence of the following purple types:—

- | | |
|------------------------|-----------------------|
| 1. Agyat | 12. Lal Kune |
| 2. Began | 13. Lal Kunwar |
| 3. Bangani (BD: 355) | 14. Lankeshawari |
| 4. Kalam Luchai | 15. Luchai Nag Kesar |
| 5. Bhundu | 16. Luchai Nag Kesari |
| 6. Bhagat | 17. Malko |
| 7. Kali Koliyari | 18. Mancha |
| 8. Kari Koyali | 19. Nag Kesar |
| 9. Krishna | 20. Nagkesar Bhondu |
| 10. Krishna Luchai | 21. Nagkeshar |
| 11. Lahbari (BD: 1293) | 22. No.11/2. |

Rice varieties with pigmentation in different vegetative parts, found in rice growing states of India are recorded below for ready reference for utilisation in increasing rice productivity through the application of genetic knowledge, as exemplified above. At present their use remains confined to irradicate wild rices from the rice fields only.

Rice growing states in India.	Improved rice varieties with pigmented vegetative parts (Richharia, 1966)
1. Andhra Pradesh	<i>Hr. 8, Mtu. 3, Mtu. 4, Mtu. 16, Mtu. 20, Slo. 9 and Slo. 12.</i>
2. Assam	<i>Ar. I, Sailbadal, Sl. 240 (Johari)</i>
3. Bihar	<i>Br. 11, Br. 12, Br. 25.</i>
4. Maharashtra & Gujarat	<i>Antersal 67, Kada 176-2.</i>
5. Jammu & Kashmir	<i>Ch. 1039, Baber, Begum, Shenei, R. 3073.</i>
6. Kerala	<i>Ptb. 1, Ptb. 4, Ptb. 5, Ptb. 8, Ptb. 9, Ptb. 12, Ptb. 16, Ptb. 18, Ptb. 20, Ptb. 21, Ptb. 24, Ptb. 26, Ptb. 27, Ptb. 29, Ptb. 30, Ptb. 32.</i>
7. Madhya Pradesh	<i>R. 2 Nungi, R. 3 Sultugurmatia, R. 4 Surmatia, R. 7 Ajan, R. 8-A (Benisar), Hybrid Paddy No. 19 (Cross No. 19), Hybrid Paddy No. 51, Hybrid rice No. 116 (Cross No. 116), Nagkesar, C.P.I., CP. 9, Cross-I, Cross B-11/2.</i>
8. Tamilnadu (Madras)	<i>CO. 4, CO. 9, CO. 16, CO. 22, CO. 23, CO. 26, CO. 29, CO. 30, Asd. 3.</i>
9. Orissa	<i>T. 56, T. 442, T. 1145, T. 1242, J1, J2, J5, EF. 86.</i>
10. Punjab	<i>L. 12, P. 502, P. 575.</i>
11. Uttar Pradesh	<i>Sudha.</i>
12. West Bengal	<i>Bank. I, Bank. 4, Bank. 5, Bank. 6, Bank. 9, Bank. 11, Bank. 15, Chin. 2,</i>

13. Manipur *Chin. 4, Chin. 6, Chin. 8, Chin. 11, NC. 324, NC. 385, NC. 1626, OC. 52. Chahao Poireiton, Plougak, Mairangphou, Jumai.*
14. The Central Rice Research Institute, Cuttack (Orissa). *CR. 102, CR. 201, CR. 203, CR. 204, CR. 208, CR. 209, CR. 211, CR. 212, CR. 901, CR. 903, CR. 904, CR. 905, CR. 906, CR. 907, CR. 3001, JBS. 120, CP. 12.*

6. *Cytoplasmic inheritance for high fertilization responsiveness and vegetative propagation*

Studies on the inheritance of nitrogen response in *japonica*, *indica* and their hybrids show that the F_1 hybrid behaved like the *japonica* (high fertilization responsive character, (HFR) when *japonica* was the female parent and like the *indica* (no high fertilization responsive character (NHFR) when the *indica* was the female parent. It appears, this is a case of cytoplasmic inheritance. These facts indicate a new approach to increase rice production through clonal propagation technology by combining high fertilization responsiveness with heterosis at F_1 stage by raising a full crop by clones and the subsequent generations F_2 and F_3 by normal seedlings to exploit a little less heterosis effect. Inclusion of stiff-strawed varieties with other desired and quality characters in hybridization programme would prove advantageous for immediate gain (Richharia, 1974 P.83).

7. *Multiplication of indigenous male sterile plants by clonal technology, to any extent, utilized for 'hybrid rice' production commercially with compatible and desired pollen restorer culture.*

Once a male sterile rice plant is discovered in an indigenous plant population of rice, it can be maintained perpetually and multiplied vegetatively. Male steriles may also be made available from other sources, retained and multiplied clonally and their utility may be judged under new environments. In combination with suitable pollen storer lines, hybrid rices may be produced to exploit hybrid vigour under any environments with desired quality (Fig. 18). Dr. K. Pavitaran* has been maintaining male sterile plant since 1978 at Calicut. Maintenance of haploids, polyploids and trisomics with special efforts through clones for genetic studies has been a regular practice adopted at the Central Rice Research Institute, Cuttack, ever since.

'CRRRI dwarf (Profuse tillering dwarf) and other indigenous dwarfs can also be utilised to develop 'dwarf hybrid rices', if desired for certain situations.

8. *Rejuvenation of rice culture in general, tract-wise.*

In some traditional rice growing areas rice growers often complain that the productivity of some of their common rice varieties is gradually deteriorating in general. This deterioration is very much marked in renowned and scented types which fetch higher prices in the market. To maintain their quality (true to types), the experienced growers select ear-heads of the rice types at harvest for the next crop which they multiply for bulk production. Exchanging seeds between

*Personal communication

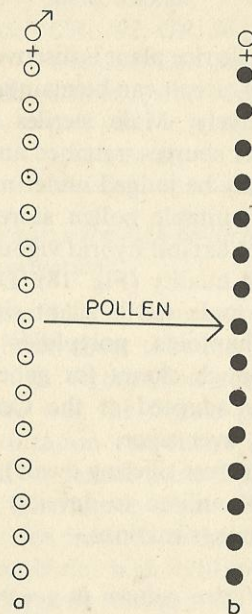


Fig. 18 An Indigenous male sterile, multiplied clonally and utilised for F_1 lines, derived from a local rice cultivar.

- a) A normal local compatible rice cultivar line selected from a locality with desirable characters, grown from seeds.
- b) A male sterile, multiplied clonally.

themselves is also normally practised. This selection procedure is followed, year after year, more rigorously for quality aromatic rice varieties. This leads to inbreeding effect, gradually deteriorating grain productivity. This is one of the major factors, compelling the farmers to reject certain types, due to low economic returns. The aged rice growers often cite examples of certain rice types within their memories, the cultivation of which have been abandoned mainly because of low production (see Richharia, 1979, pp. 22, 23). Thus extinction of very useful rice varieties has been taking place at an alarming speed (There are other reasons for such a situation as well). To avoid such a situation, it is now possible to rejuvenate and genetically upgrade the rice culture locality-wise, embracing several adopted rice cultivars leading to higher productivity. This can be done by resorting to hybridization between ecotypes/eco-strains of a major group of rices or field cultures, showing distinct variation in a principal rice variety (See Richharia, 1979, pp. 4-10 and Richharia, 1978, pp. 2-15). The F_1 plants so raised are multiplied clonally to obtain enough F_2 seeds for raising field crops from normal seedlings to take advantage of hybrid vigour in the later generation, as explained in Chapters III. For information it may also be added that too much emphasis on particular rice types with narrow genetic base (such as the modern elite HYVs with dwarfing genes) to be grown in certain earmarked areas, replacing all the existing indigenous adopted cultivars leads to deterioration in productivity and stabilised production in those earmarked areas and in bordering areas too, caused by a number of factors, such as inbreeding effect and other genetic causes. It is, therefore, necessary to rejuvenate the indigenous rice culture, step-by-step with individual varieties by introducing vigour which can be easily done by involving the ecostrains of major groups of rices and

variation observed in principal rice varieties in different rice growing regions as exemplified by a botanical survey, conducted in Madhya Pradesh (Richharia, 1979) and by applying clonal technology for rapid expansion, as explained below. It is indeed extra-ordinary to observe how the tribal rice farmers maintain vigour of the rice culture in their environments, practised with their individual rice cultivars, yet to be understood fully. One such method practised by them is referred to under Chapter VI (page 59)

An example to rejuvenate a rice culture of Gurmatia group of paddy in Chhattisgarh (M.P.)

Lambi Gurmatia

Sulti Gurmatia

X
F₁
(multiplied clonally)



Normal rice crop raised from F₂ seeds with vigour

An example to rejuvenate a rice culture of a principal rice variety Ajan in Chhattisgarh (M.P.)

Eco-strain A*

Eco-strain D*

X
I
F₁
(Multiplied Clonally)



Normal rice crop of Ajan raised from F₂ seeds with vigour

* See Richharia, R.H. (1979, pp.5-6).

CHAPTER VII

OBSERVATIONS RECORDED ON CLONAL PROPAGATION TECHNOLOGY IN DIFFERENT RICE REGIONS OF INDIA

The technique of clonal propagation has been tested at a number of research centres in different rice growing states. Results available are summarised below:—

Mysore: Yield upto 6000 pounds per acre has been reported under clonal propagation method of planting with *Adt. 3*, as against the yield from the seed crop which was recorded to be upto 3,200 pounds per acre (Richharia, and Govindaswami, 1966 : P. 178).

Andhra Pradesh: Observations recorded by M.V.S. Shastri and V. Rajagopala Reddy (1967) (*c.f.*, Richharia, 1967; pp. 22, 26).

Exploiting the hybrid vigour through vegetative propagation was practised by several workers in India. Extensive trials were undertaken at Central Rice Research Institute, Cuttack and tangible results were obtained by resorting to clonal propagation. Richharia (1960) observed that the F₁ of the cross *W. 114* × *GEB. 24* had got hybrid vigour and the F₁ plants were multiplied vegetatively to exploit the hybrid vigour. One stubble of this cross *W. 114* × *GEB. 24* F₁ brought from Central Rice Research Institute in 1961 was multiplied in 1961 onwards. In the main crop season of 1962 a population of 1650 plants was raised with a nett plot size of 1100 sq.ft. which took only three months. An yield of 32 lbs. was obtained from this plot. Due to its profuse tillering habit and its capa-

city to withstand the heat of summer months, it was successfully multiplied. It was proved that vegetative propagation is the best way of exploiting the hybrid vigour. The cross showed the inherent capacity for drought also.

In addition to the above trial, another trial was undertaken by multiplying the seedlings and planted. The main purpose was to multiply a large area with very limited seeds. It was observed that the yields were doubled in some cases by resorting to this clonal propagation.

The three popular varieties of the State, *Mtu. 15*, *Mtu. 3* and *Slo. 16* could also be multiplied vegetatively

Bihar:—(Observations recorded by V.A. Kulkarni, 1967
(*c.f.*, Richharia (1967); P.89).

Vegetative propagation was practised by various workers to exploit hybrid vigour in plants. Considerable work has been done in this regard at the Central Rice Research Institute, Cuttack. Richharia (1961) observed that F_1 of the cross *W. 114* × *GEB. 24* had hybrid vigour and the F_1 plants were multiplied vegetatively to exploit hybrid vigour.

Five stubbles brought from one of the plants of the mid-early duration type *Ac.4160*, a variety from NEFA maintained in the Genetic stocks, at the Central Rice Research Institute, Cuttack, during the main season of 1962-63 were multiplied at the Agricultural Research Institute, Patna, to 4450 stubbles between the period from 4.1.63 to 21.7.63 and were planted in 7.5. cents. The stubble planting gave 2240 kg/ha. of grain yield. The plants did not lodge even under high fertility dose and were free from diseases and pests. Thus within one season sufficient plants so as to cover an area of 7.5 cents were obtained from only five stubbles.

KERALA: (Observations recorded by G.Gangadharan and A.J.Chacko (1967) (*c.f.*, Richharia, 1967; p.131)

1) In the F_2 population of the cross *Norin. 1* × *Ptb. 10*, grown during the 3rd crop season of 1963-64 (January to April), a few vigorous plants were seen which did not come to flower at the end of the season. One of the plants was uprooted and the tillers were separated and each tiller was planted separately. They came to flower only in November and were harvested in December. It was found that each tiller developed into high tillering plants and they were high yielders. There were seventeen plants and the ear-bearing tillers ranged from 47 to 70 and the single plant yield from 87 to 196 gms. The plants were also found to be highly fertile. These selections were to be tried in the second crop of 1965-66.

2) Two varieties *CR. 201* and *C.R. 2002* were supplied by the Director, Central Rice Research Institute, to the Chief Agronomist. F.A.C.T. to assess the efficacy of clonal propagation. The varieties were sown in April and the tiller splitting was done twice on 10.5.1964 and 9.6.64. The seeds were sown in an area of 1/2 cent for each variety and by vegetative propagation each variety covered an area of 2 cents. *i.e.*, four times the initial area by two splits. *C.R. 201* was reported to have a total duration (seed to seed) of 173 days and *C.R.2002*, 193 days. The yields obtained from those varieties by this method of propagation were high, 3600 lb/ac for *C.R. 201* and 4000 lb/ac for *C.R. 2002*.

Indian Agriculture Research Institute, New Delhi.

Zaman *et al* (1985), recorded that a preliminary study using split seedlings indicated that it may help in planting 3-4 times increased area without any loss to the yield.

Madhya Pradesh: The author continued the work between 1971 and 1979 on the technology at the Adaptive Rice Research

Centre, Baronda (Raipur), utilising the method in different ways. The technique was utilized in the maintenance of the rice germplasm collection annually.

Orissa: (Observations recorded by extension workers)

Demonstration of technique of vegetative propagation in Cultivators' fields (repeated from pages 40-41).

During the main crop season of 1963 an intensive effort was made to popularise the technique of vegetative propagation through twenty-five demonstration trials in 10 different villages of the neighbouring Cuttack Sadar Stage II Block. The yield potential of vegetative propagation technique was tested in four improved varieties viz., GEB.24, J.192, T.141 and T.1242 against a local variety. The results are presented below:

Response of vegetatively propagated seedlings and stubbles within the season in increasing the yield—Grain yield in kg/ha.

Variety	No. of experiments conducted	Normal crop	Crop from vegetatively propagated seedlings (V.P.)	Stubble crop	Percentage on normal	
					V.P.	Stubbles
GEB. 24	13	2643	3786	3236	143	123
T.141	10	2626	3451	1964	131	75*
J. 192	1	3182	4318	....	136	....
T. 1242	1	1482	2963	....	200	....
Local	23	2187	3157	....	144	....

* The crop showed symptoms of bronzing from the beginning, resulting in reduced yield.

Variety × Method—Grain yield in kg/ha

Method	Variety			Percentage of increase over normal	
	GEB. 24	T. 141	Mean	GEB. 24	T. 141
Normal . . .	2615	2826	2721	....	....
V.P. . . .	3771	3695	3733	44.2	30.8
Stubbles . . .	3300	2090	2635	26.2	(-26.0)
MEAN . . .	3229	2870	3050	....	....

C.D. 5% to compare the means of the methods=396

C.D. 5% to compare the means of the body of the table (V × M)=560

Vegetatively propagated crop, in general, has given substantially higher yield than the normally raised crop in all the varieties; thus establishing the superiority of this technique. *Uttar Pradesh*

Shri Balakrishna Rao, working at Faizabad during the period 1960-65, confirmed the utility of vegetative propagation in those environments. At the Agricultural Research Institute, B.H.U. Banaras, an experiment was conducted by Richharia and Madhuri Lata (1966) with 16 rice cultivars of *indica* group under three methods of planting viz., (1) Normal planting, (2) double nursery method (replanting of seedlings, two weeks after transplanting on the original hills) and (3) Vegetative propagation method. Varietal difference was observed, comparing with the normal method as a base in terms of percentage increase or decrease in grain yield: 4 cultivars showed increased yields with vegetative propagation method as compared with the double nursery method and normal planting. Negative results were also observed in both the planting methods, as compared with the normal. This

means, for individual genotypes, suitable methods of planting should be identified to obtain maximum production in the environments where they are grown.

West Bengal: Experiments, carried out at Chinsurah (West Bengal) on clonal propagation in rice.

In West Bengal the rice variety *Bhasamanik* gave 4414 kg/ha from tiller plants as compared with the yield of crop raised from seeds which gave 3070 kg/ha, whereas the other rice variety, *Patnai 23*, yielded 4169 kg/ha from tiller plants and 3041 kg/ha from normal seedlings (seed plants).

Mitra and Paul (1967) had carried out some detailed investigations on clonal propagation in rice at the Rice Research Station, Chinsurah (West Bengal) as reproduced from the authors' original paper (*c.f.*, Richharia, 1967 pp 298, 301 & 303) for ready reference.

A study on the clonal propagation with two local *aman* varieties, namely *Patnai-23* and *Bhasamanik* was taken up during the year 1963. Seeds were sown in pots by the third week of May, 1963. To start with, for each variety 10 healthy seedlings were taken and tiller separation and replanting were done in the field at regular intervals. After the fourth and final tiller separation, which was done during the first week of September 1963, the number of tiller plants for *Bhasamanik* and *Patnai-23* was 715 and 639 respectively.

These tiller plants and the seed plants obtained from the seed bed, were grown on equal size plots for a study of their comparative performances.

The tiller plants proved to be more vigorous; they were taller and produced more number of fertile tillers than the seed plants. It is interesting to note that although the time of flowering of both the seed and tiller plants was the same, it was observed that the seeds on the tiller plants matured

earlier than those on the seed plants. Yield of the tiller plants was also high (Table XIII of the original paper).

For the tiller plants, the percentage of increase of grain yield over the seed plants was 43.7% for *Bhasamanik* and 37.1% for *Patnai 23*. The percentage of increase of straw of tiller plants over the seed plants is also very high; for *Bhasamanik* it is 58.1% whereas for *Patnai-23* it is 50.0%.

The increase in yield obtained as a result of tiller separation technique shows that tiller separation has some significant beneficial effect on growth and yield of these varieties. This confirms the observations of Dr. Richharia (1961) who was first to detect the usefulness of tiller separation in rice. It appears that tiller separation retards the action of certain physiological inhibiting factor (say hormone), which controls the growth of secondary and tertiary tillers, or in other words, in rice, by tiller separation apical dominance is reduced.

A study on the relative efficiency of vegetative propagation on Aman varieties.

For this study two local varieties namely *Bhasamanik* and *Patnai-23* were taken up. These were sown in plot in May 1962 and first tiller separation was done in the third week of July. For this experiment 6 healthy plants of each variety were taken. In three of them tillers were separated and the other three, where the tillers were not separated, were used as control. Individual tillers were separated and were transplanted in the field in a line, allowing a space of 6" between plants and 12" between lines. The control plants were also transplanted in the field. A second transplanting was done by the middle of August 1962, when the individual plants of the first transplanting were again vegetatively separated into three more or less equal parts and planted in the same plot with a

TABLE XIII (reproduced)
Comparative performance of Seed and Tiller plants in Rice
(1963)

Characters	Net plot size for Bhasamanik 12' 9" × 19' 6"		Net plot size for Patnai-23 11' 3" × 19' 6"	
	Bhasamanik		Patnai-23	
	Tiller plants	Seed plants	Tiller plants	Seed plants
1. Height (cm.)	137.9	116.9	125.6	121.1
2. Fertile tillers	7.4	5.9	7.6	5.5
3. Grain yield per plot (kg.)	10.2	7.1	8.5	6.2
4. Percentage of increase of grain over seed plants	+43.7	.....	+37.1	.....
5. Grain yield (kg./ha.)	4414	3070	4169	3041
6. Straw weight per plot (kg.)	13.5	8.5	12.0	8.0
7. Percentage of increase of straw over seed plants	+58.1	.....	+50.0	.....
8. Straw weight (kg./ha.)	5842	3678	5886	3922

spacing of 4" × 6". To keep a symmetry, the controls were also transplanted for the second time without disturbing their tillers.

Thus at the final stage it was observed that 3 Bhasamanik and 3 Patnai-23 plants by vegetative propagation produced 117 and 78 plants respectively. The detailed data are presented in Table XIV of the original paper.

In Bhasamanik and Patnai-23, the vegetatively propagated plants produced 18 ozs. and 20 ozs. of grains as against the three normal, undisturbed plants of each variety, which together produced only 6.5 oz. and 13 oz. grains respectively.

Thus from the above experiment it appears that vegetative propagation increases the efficiency of mother plants to produce more tillers and grains and the degree of efficiency varies from variety to variety.

TABLE XIV (reproduced)
Relative efficiency of vegetative propagation on Aman varieties

Date of sowing 16-5-62.											
Variety	Date of first trans-planting	No. of plants used	Total no. of plants of the first trans-planting	Date of second trans-planting	Total no. of plants after 2nd trans-planting	No. of days taken to flower	Average days tillers	Average length of panicle (cm.)	Total yield in oz.	Yield in gms.	
<i>Normal transplanting :</i>											
Bhasamanik	21-7-62	3	3	16-8-62	3	163	28.0	23.2	6.5	182	
Patnai-23	21-7-62	3	3	16-8-62	3	162	25.7	24.3	13	364	
<i>Vegetative propagation :</i>											
Bhasamanik	21-7-62	3	39	16-8-62	117	163	6.4	24.6	18	500	
Patnai-23	21-7-62	3	26	16-8-62	78	163	5.0	27.0	20	558	

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CHAPTER VIII

IMPORTANCE OF CLUSTERED PADDY CULTIVARS WITH SPECIAL REFERENCE TO CLONAL PROPAGATION TECHNOLOGY

Clonal propagation technology provides a special advantage to utilise the clustered—grain rice-type (Fig. 20) in cross-combinations, to obtain higher production from the combined effect of hybrid vigour through heterosis and intensified density of grains on the panicle, besides other desired combinations. The F_1 plants are clonally multiplied to obtain enough seeds for F_2 generation, raised as a full crop of rice from the seeds. (also see pp. 43, 56 & 97). Increased yield of grains is obtained, as majority of the F_2 plants possess clustered grains in the panicle, because clustering of grains, nature and arrangement of which is under variable genic-control as explained below. Thus the genetic constraint is resolved to obtain more grains per unit area, Success would much depend on the selection of parents, involved in the hybridization programme, such as a rice cultivar with long panicle with normal grain arrangement, crossed with a cultivar, possessing super-or normal clustered grains (Fig. 19).

Quality of rice grain and maturity period are other characters to be taken into account while selecting the parents for hybridization.

Occurrence of clustered paddy types is not very uncommon, if special efforts are made to locate them especially from places where the rice culture still continues comparatively undisturbed. In a recent botanical exploration, 48 types of the clustered group (designated as 'The rice varieties of the future') were collected from parts of Chhattisgarh in Madhya Pradesh (Richharia *et al*, 1978: p. 24; Richharia,

(1979) majority of which were located in a particular region (Fig. 21). If a 'male sterile plant' from the clustered group is secured, the yield potential of F_1 seeds (hybrid rice) is also enhanced manifold (*i.e.*, the economic production of hybrid rice becomes easy), leading to increased rice productivity.



Fig. 19: Two panicles of a super-clustered rice variety (*Chhind dhan*), showing clustering of spike-lets

The tetraploid forms of clustered types would also further widen the scope with the aid of clonal technology to produce tetraploid rice grains with higher protein contents (also see Chapter IV).

According to linkage studies in rice, clustered spike-lets governed by the gene *Cl* is, located in "WX" group (1) and in "LX" group (XI) corresponding to 'be' linkage group of *japonica* (*c.f.*, Misro *et al*, 1966); whereas based on studies of trisomics, genes for clustered spikelets Cl_1 , Cl_2 , Cl_3 are assigned to chromosome 12, 8 and 7 respectively (Misra *et al*, 1983).

It may be mentioned that the plant breeder, dealing with the variability of local rice germplasm and hybrid population, if vigilant, may locate such plants as clustered types, dwarfs, male steriles, trisomics, haploids, triploid, tetraploids and plants with abnormal floral structure *etc*, which spontaneously appear in the mixed and segregating plant population but which get eliminated as unwanted plants.

UTILIZATION OF CLUSTERED RICE TYPES RAISING RICE PRODUCTION IN MULTIPLE

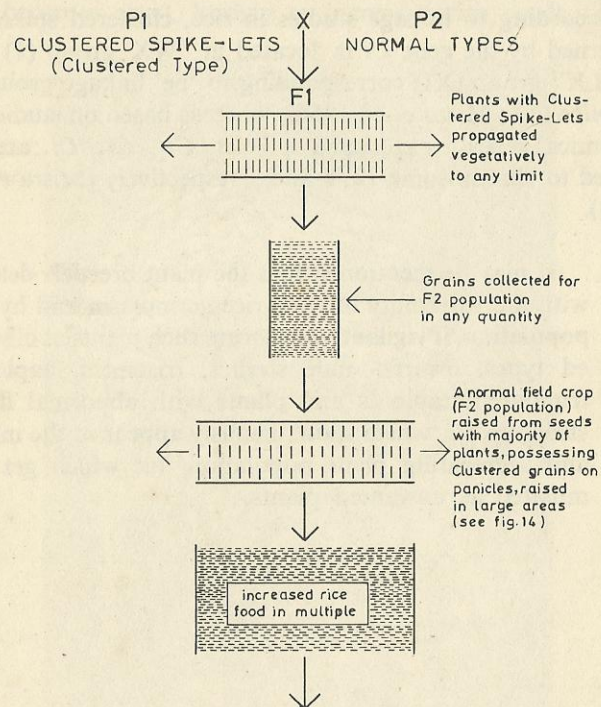


Fig. 20 use of clustered rice cultivar in exploiting hybrid vigour and clustered spike-let character with the aid of clonal propagation technology.

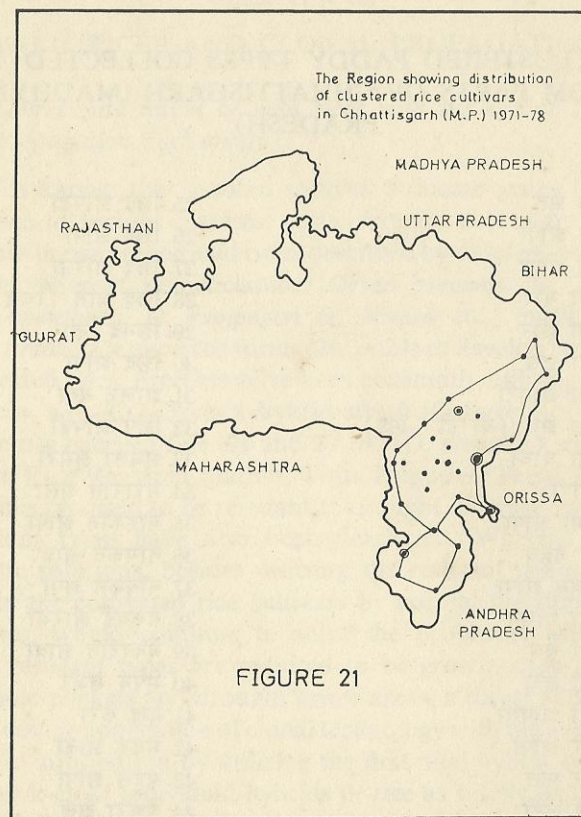


FIGURE 21

Fig. 21. An out-line of Madhya Pradesh, depicting the region, where concentration of clustered rice types was observed. (Reproduced from Richharia, 1979: Fig. 5)

**CLUSTERED PADDY TYPES COLLECTED
FROM PARTS OF CHHATTISGARH (MADHYA
PRADESH)**

- | | |
|--------------------------|------------------------|
| 1. अमा झुल | 25. छिद झोपड़ी |
| 2. अमा झोपा | 26. छिद झोपा |
| 3. अमा झोपा | 27. छिद झोरपा |
| 4. अमा गौर | 28. छिद धान (चित्र 19) |
| 5. अमा झार | 29. छिनद स्ती |
| 6. अमा झुल | 30. छिद झोपा |
| 7. अमा झोयरी | 31. झालर गेंदा |
| 8. अमा झुल (वी डी : 498) | 32. झिप झोपड़ी |
| 9. अमा धोंधा | 33. झुमका झुमेरी |
| 10. कन्होरी | 34. मरारीन झुला |
| 11. कुसमी झोपा | 35. नाइकीन झोपा |
| 12. केरा गहूध | 36. नायकन झाबा |
| 13. कोल्हेन झोपा | 37. नायकन झुपा |
| 14. कौड़ी गाथन | 38. नेकवई झोरथा |
| 15. कौड़ी धुन | 39. नेकारीन झोबा |
| 16. कौड़ी झुल | 40. मेपेन खजुर |
| 17. कौड़ी झोपसा | 41. बल केरा |
| 18. खजुर झोपा | 42. मकई झाबा |
| 19. खजुर फुल | 43. महुल झोपा |
| 20. गंजई लटी | 44. मेकरा झुल |
| 21. गोंदा फूल | 45. रानी फुदरी |
| 22. चिराई झुल | 46. रूनी पाईख |
| 23. छिद झोयरी | 47. लहसुन धान |
| 24. छिद झोथा | 48. हिंद स्तीन |

**CHAPTER IX
WILD RICES AND CLONAL PROPAGATION**

(*Direct utilization of wild rices with the aid of Clonal Propagation Technology*).

It is known that assured sources to locate genes for resistance to various diseases, pests, drought and many other stresses in rice are the wild rices, described by different workers under different nomenclature: *Oryza perennis*, *O. Sativa* Var. *spontanea*, *O. rupipogon* *O. Nivara* etc., particularly their immediate ancestor forms ($2n = 24$) to develop resistant cultivated rices. Breeders have been constantly utilising those sources, e.g., CO. 31 is a hybrid strain (Culture No. 9754) of a cross between *Geb. 24* and *T. 260* (*O. perennis*), evolved at the Rice Research Station, Tirur Kuppum (Tamil Nadu) which is reported to be resistant to drought. Disease and pest resistant types have also been developed. Whereas, such genetic solutions, besides utilizing the resistant genes from within the cultivated rice cultivars by normal breeding procedures, would continue to solve the problems, wherever such resistant types are required to be grown, such as the endemic pockets and drought prone areas, a direct approach involves the application of clonal technology with the available genetic information by utilizing the first filial hybrid or even the back-cross individual hybrids in rice as briefly explained below. Epidemic situations can be faced and the use of insecticides and pesticides can be avoided which are hazards to human health.

Any indigenous—desired rice improved type (susceptible to any disease, pest, drought etc.) can be crossed with a wild form of *O. perennis* and other related forms with which it

would readily cross, possessing resistance genes. The F_1 plants in some cross combinations would express dominance of resistance to the prevailing genetic constraints including grain shattering, (spike-let shattering being the characteristic feature of the wild rices.)

Such F_1 plants can be multiplied vegetatively to produce clones to any extent, to cover especially the problem areas or any desired area such as 'hot spots' for gall-midge and the blast disease etc. (Fig. 22)

Thus two factors work to keep the rice crop free from the constraints viz., (1) physiological capacity of the clones to resist the environmental stresses, coupled with hybrid vigour and (2) genetic dominance. Enough information is available on the inheritance of resistance against many diseases and pests involving a number of genes, but we are here concerned not so much with the identification of the genes involved, but only with the genetic *dominance* expressed at F_1 or a back-cross which can be projected by clonal propagation technology, and further we are only concerned with the resistance genes derived from the wild rice, and due to the existence of immense genetic variability in the local rice germplasm of both wild and cultivated rices, suitable cross-combination may be located by undertaking intensive hybridization programme.

Thus dominance of resistance against the constraints can be assured at F_1 generation, derived from the wild types. But the major draw-back of shedding (shattering) of grains, characteristic of the wild rice, also requires solution; here also it is equally true that in certain cross-combinations, non-shattering habit may be found to be dominant e.g., Kadam (1936). observed grain shedding of the wild rice to be dominant to non-shedding and controlled by two genes Sh_1 and Sh_2 , but Ramiah and Rao (1936), on the other hand,

record non-shedding to be dominant and due to more than one gene. It is thus evident that a great scope exists to develop F_1 or back-cross plants, deriving resistant genes from the wild forms and non-shedding cum-long dense/clustered spikelet panicles from the cultivated types. The clone-plants, made available to any extent, may be planted in the desired localities. Such an approach would naturally involve manual labour, but the rice farmer does not hesitate to put any amount of physical strain, provided he is convinced that he can obtain extra rice food.

It must be emphasised that utilization of wild rice forms, involves: (1) Intensive hybridization programme to locate appropriate forms from the wild and cultivated types to be hybridized, which is not considered a difficult task, in view of the presence of high genetic variability in the wild and cultivated forms of rices and (2) Only F_1 and individual back-cross plants, followed by cloning, are to be grown as a full crop of rice (with clones), combining, resistance and high yields due to hybrid vigour effects, unlike the other approach to exploit hybrid vigour with hybrid rices at F_2 generation, involving cultivated types only, as discussed, in Chapter VI.

It is, however, of some interest to record that utilization of clustered group of paddy and involving cultivated purple types in combination with wild rice forms (Purple wild forms do not exist now). and getting rid of green seedlings with grain shattering, raised at F_2 stage and then raising a full crop of rice with left over F_2 plants showing resistance, on the same pattern as explained under chapter VI (5), p. 71 deserves attention of the rice breeders.

In brief, it is known that wild rices of the *perennis* group which cross readily with the cultivated rice types possess useful resistance genes, expressing dominance at F_1 generation when crossed with the susceptible cultivated types in certain

cross combinations and in many of such combinations, non-shattering grain character is also observed to be dominant. These facts have been utilized to exploit wild rices through F_1 and or back-cross plants, cloned to any extent and grown particularly in desired problem localities. The rice farmer is not afraid of manual labour and would willingly accept this technology or any other method once he knows that more rice food can be raised, provided the utility of the method is demonstrated on his land.

DIRECT UTILIZATION OF WILD RICE FORMS THROUGH CLONES

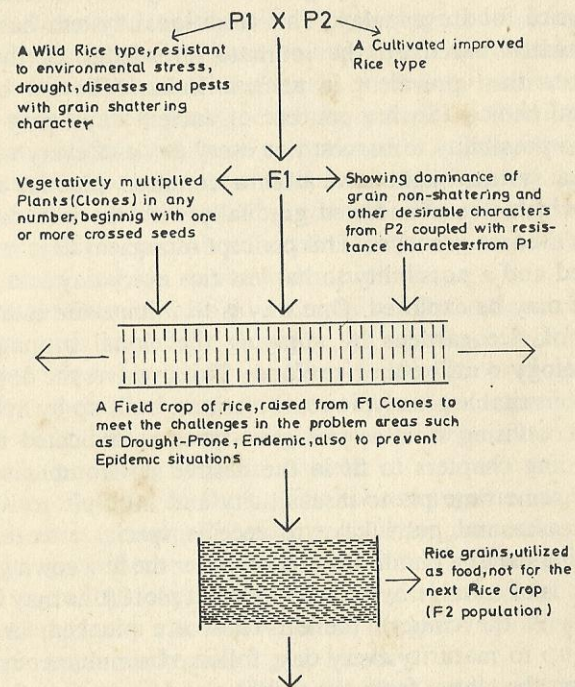


Fig. 22. Exploitation of resistance genes from wild rices by the application of clonal propagation technology.

CHAPTER X

ESTABLISHMENT OF RICE GARDENS

At the Puri temple in Orissa, the paddy crop is harvested every day and the Lord Jagannath is worshipped with that fresh rice food every day. This traditional system has been propagated based on the intimate knowledge of the rice varieties then prevalent in ancient India, followed by the varietal choice. (Such a concept of ancient days, may guide us to a possibility to harvest rice every day and every where). Such a system might have been a common practice in the past which was abandoned gradually with the introduction of the modern practices. This concept of ancient days may be revived and a possibility to harvest rice every day and every where may be explored. One way is to initiate the establishment of rice gardens by applying the clonal propagation technology to utilize the rice clones. This involves the development of suitable genotypic combinations, built up by hybridization, utilising suitable rice geno-types as indicated in the fore-going chapters to fit in the desired environments, and at the same time photo-insensitivity and multiple resistance to diseases and pests have to receive special attention in choosing the first planting material. After the first sowing with the seeds of suitable hybrid rice in small plots (this may begin even with the clones), the ear-heads are plucked, as they come up to maturity every day, followed simultaneously by splitting the clones from the stubbles and replanting them at nearly the same locations. The process may continue with individual plants as and when ready and as long as it can stand, perhaps a few years, (without carrying out re-sowing with fresh seeds), coupled with every day collection of rice grains. With such an endeavour, an estimated rice production

may even exceed a hundred tons per hectare annually. An assured water supply and management, manuring, weeding, drainage are the essential pre-requisites to establish rice gardens and it is not considered difficult to manage such small garden plots, the sizes of which may vary with the guaranteed resources, including manual labour.

Rice breeders, agronomists, physiologists and microbiologists can come forward to apply their knowledge and experience in such restricted areas, as an intermediate step, by evolving suitable genotypes of rice, coupled with soil-water management practices (such as optimum water requirements in relation to the soil type and its fauna and flora etc.) under the desired environments. This concept of crop gardens is a most scientific approach of a permanent value and should not be confused for national demonstrations.

Such gardens may also go a long way in the conservation of habitats, rich in genetic diversity, an approach which has been practised for centuries. With locally adopted genetic diversity, such local rice gardens will become a permanent source of knowledge and will serve as demonstration units for the surrounding farmers as well.

It is known that in the traditional rice regions local rice germplasm is principally characterised by possessing very rich rice genetic variability as exemplified in recent years by the author (Richharia, 1979) and many others in India. Such attempts can also be combined for growing other agricultural crops predominating a locality.

Intensive cultivation is a key to feed the estimated 8 billion peoples of the world by the beginning of the 21st century, instead of extensive cultivation, thus leaving a reasonably large surface of the earth for the survival and growth of the natural fauna and flora for ecological balance to escape pollution in the future. Establishment of rice gardens, more so, when the

rice-eating habit is on the increase, deserves priority to welcome the future generations for all times to come.

Where there is a will there is a way

There exists an immense possibility of establishing such crop gardens in the rural areas, associated with the primary schools as well, without any extra resources, utilising the school compounds. This will also serve the purpose of educating the young minds in intensive crop production methods, especially with food crops of their locality to meet the challenge of increased food demands of the future. To quote an example from Madhya Pradesh: There are about 45,000 primary schools, most of which being located in rural surroundings. Further Government's proposals are to develop botanical gardens in all the 45 districts of the state as a measure to control pollution which can be linked with such crop garden projects without any extra resources.

As a long range programme to safeguard the future, protected forest areas and national parks to preserve the wild plant species, closely related to cultivated crop varieties (including wild rices) under their natural habitat may be recognised and linked with the forest National parks already established to protect the wild lives. Such approaches will not involve any extra resources except realizing the significance to preserve the fauna and flora (both micro and macro) of possible utility in the future.

Birth control, as it is, does not offer an assured solution to restrict the population at a particular level. It may or may not succeed against the Nature's law of evolution. Ultimately the solution lies in producing food for all and it is possible only through projections based on our scientific knowledge alone. Bringing in political considerations would prove disastrous for human welfare.

CHAPTER XI THE FUTURE PROJECTIONS

From the foregoing account of the rice work, it is evident that we are on the thresh-hold of entering a possible rice revolution, if this approach is initiated simultaneously at all levels with rice clones and cloning, as a basis of taking advantage of latent energy of the rice plant, coupled with hybridization and natural out-crossing within or and between rice cultivars, including the wild forms. To investigate the behaviour and response of the rice clone in space during the Cosmic journeys, because of the perennating nature of the clone, would be a very fascinating subject aiming at providing food to the travellers in space and inhabitants of the space townships yet to be established. It is an indigenous technology with indigenous material for indigenous environments. This would enable the rice farmers to take advantage of the hybrid vigour phenomenon through hybrid rices as a direct contribution made by the rice scientists of all disciplines who would get the opportunity to apply and to project their genetic knowledge of the rice plant by intensive field experimentation. These efforts, as out-lined here, also envisage cooperation of such existing national and state organisations as the Seed Corporations and agricultural societies. Even the local enlightened rice farmers can be directly involved in improving their rice culture, simultaneously giving advantages to their brotheren with small holdings through the technology, described here.

In brief this work may be taken as a genetic forecast to introduce a possible silent revolution in up-grading the yield potential of the rice culture wherever it is practised in over 110 countries of the world in general and India in particular.

To start with, as my personal contribution with a thrust

on the collection, conservation and utilisation of the indigenous rice germplasm which is our heritage, I have established with voluntary cooperation of Sri Aurobindo Ashram, the following two centres for providing information and intensive training to initiate a chain reaction in increasing rice productivity in relation to prevailing environments. The third centre is under contemplation to be located somewhere in the Chhattisgarh region which is the rice bowl of Madhya Pradesh. Invitations are extended to all interested in this major staple food of humans to establish such voluntary rice centres with local resource and readily available inputs to ensure increased rice production and productivity, meeting the demand of the expanding human population.

To strengthen the hands of Government of the Country in such vital matters as food for millions, is the concern of all who can make substantial contributions, intellectually, financially, physically and even psychologically.

It is from this point of view that I extend this invitation to establish such self-propagating rice centres of knowledge, spread all over the rice regions.

No magnitude of planning on the food front would work according to expectation, unless it is village-oriented, with prevailing socio-economic environments.

1. Jaiamba Land,
R. Plant Breeding Centre,
Village: Sagonikala,
Raisen Road, Bhopal-462 023.
(Madhya Pradesh).
2. Gloria Land,
Sri Aurobindo Rice Research Centre,
Aurobindo Ashram,
Pondicherry-605 002.

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APPENDIX I

A communication on utilisation of hybrid vigour in rice: released in 1961, Reproduced from Supplement to SPAN Vol. 4 No.I, 1961: p. 27) Richharia, 1961).

Rice is a self-fertilised crop and, therefore, commercial production of F_1 seed is a problem, as each cross results in only one hybrid seed. The problem of mass production of crossed material is to be solved. As far back as 1961 the following observations were recorded:

Utilisation of Hybrid vigour

A considerable degree of heterosis has been observed in *inter-indica* $\times$ *japonica* hybrids and also in *intra-indica* hybrids for the number of ear-bearing tillers and height. Considerable increase in yield (8.3 per cent. to 230.2 per cent.) has also been noted in certain *intra-indica* cross-combinations; but, as each cross results in only one hybrid seed, the problem of mass production of crossed material is to be solved by:

- Encouraging natural cross-pollination through growing adjacently tall and short varieties of the same maturity period;
- Devising easy methods for large scale emasculation and pollination; and
- Multiplying the F_1 hybrids by vegetative propagation through stubble planting.

APPENDIX II

SEMINAR

IRRI, February 7, 1963

CLONAL PROPAGATION OF RICE AND OTHER RECENT APPROACHES TO RICE GENETICS

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The possibility of raising a full crop of rice from the vegetatively propagated plants has now been established, which means repeated tiller separation after regular intervals. It has been found possible to propagate a single stubble to a considerable bulk to occupy about half an acre of land in 4 to 5 splits between January and July. This can be calculated by a simple formula $(X)^n$, where x means average number of tillers separated each time, and n , the number of splits. It has been found possible to increase the population even within a season to about 300 tiller plants from a single seedling.

There are great advantages associated with this technique, as enumerated below:—

1. Perfect genetic purity can be assured in the seed multiplication work.
2. Exploitation of hybrid vigour in rice, both in F_1 (clonal) and F_2 (seeds), can be considered well within the reach.
3. The tiller crop is capable of yielding 200 to 300 per cent higher production.
4. The clones resist the flood condition very well.
5. An abnormally large F_2 population can be raised.

It was possible to raise a population of over 5,000 F_2 plants of a cross in the main season of 1961. During 1962, from another cross, it has been found possible to raise about 3,500 lbs. of F_1 seeds for F_2 . It is evident that millions of plants could be raised in F_2 and subsequent generations for genetical studies.

6. Enough seeds can be obtained from sterile or semi-sterile plants.
7. Haploids could be multiplied vegetatively and diploid seeds could be obtained for raising pure lines directly.
8. Similarly, gamma-rays and radio-isotope treatments administered on the vegetative buds of the haploid plant may be able to induce structural changes, and this may be doubled, which would result in new diploid plants (*cf.* Sampath).
9. We may maintain F_1 plants perpetually for ready reference in our investigations at any future date.
10. Combinations of different complexes of genes could be developed and gene pool combination maintained. In this manner, the characters may be recovered or regained at will. It is also possible to establish cultures which would show somatic segregations which will be an additional source of creating variability.
11. Nutrio-physiological studies have indicated that the tiller plants and the seed plants behave identically.

As regards recent approaches in rice cytogenetics, our observations are that there is no necessity to repeat what has already been achieved in other crops. Let us try to draw analogy from the work of other investigators on other crops and build up further knowledge of the rice plant, rather than to re-open the question once again, with special reference to rice.

Too many hypotheses which are sometimes mere specula-

tions, if encouraged by veteran workers, lead to wastage of scientific talents; for example, pachytene analysis need not involve unnecessarily complicated interpretations. Enough work has been done in maize and other crops, and cytological preparations in rice could be straightly interpreted correctly on that basis, in the majority of cases, instead of making fresh approaches.

We may also straightly accept the suggestion made that the linkage groups in the sub-species of *Oryza sativa* would differ in details. The cultivated rice material shows tremendous variation morphologically and in the arrangement of structurally changed chromosomes and, therefore, the linkage value obtained by different workers for similar situations may also not tally. It is suggested that we first work out two sets of linkage groups separately for *Japonica* and *Indica* types respectively, by utilizing only standard varieties to be employed by all workers in their own countries and elsewhere. Once this is done, we will understand the rice plant better genetically and interpret such complicated problems as sterility, whether it is genic or environmental, and whether the character for high fertilization response is genic or environmental, etc. It is hightime now that we rapidly complete this inquiry and attempt to exploit linkage knowledge to achieve economic results [for example, J.B.S. 120 (purple) $\times$ T14 (green)]. It should not be difficult to rogue out undesirable linked genes at F_2 stage from a field population raised from clonally propagated F_1 plants, referred to above.

Utilization of genes from the wild rices is of immediate importance. Nature has been doing this for us in regions like Assam and Orissa and similar other places. A continuous flow of wild genes into cultivation is taking place by this process of natural hybridization between *Oryza sativa* and

Oryza perennis and, also, perhaps other forms, followed by stabilization of desirable types under cultivation.

In India, wild rices are considered a great menace in rice cultivation. Such a situation should not be considered alarming as we are receiving useful genes from the wild flora such as the genes responsible for resistance to various diseases and pests. On the whole, the Assam rices and the varieties collected from the jaypure tract of Orissa are observed to be fairly resistant to diseases and pests, as against those in Japan and elsewhere where this type of free exchange of wild genes is practically absent, and the varieties of those regions are found to be most susceptible to diseases.

A question now arises whether or not Japan should introduce wild rices and India, protect its wild rice flora.

It is also interesting to note that it is only the cultivated forms which get hybridised with the wild rices but not the wild rices reciprocally. Genetic investigations directed towards this phenomenon are to be intensified. To quote an example, it has been demonstrated that it is possible to recover cultivated rice by hybridizing a wild rice from Cuba (*Oryza perennis* var, *cubensis*) and the wild rice *Oryza perennis* (*O. balunga*) from Orissa. This unexpected segregation from a cross between two wild rices is significant.

Tetraploid plants can now be produced without much difficulty in rice. The autotetraploids show a considerable amount of sterility, but the grain size is bigger and the protein content higher than their corresponding diploid.

The tetraploid, however, cannot stand competition with the diploids and generally produces a few tillers. Therefore, if suitable agronomic conditions are involved, the tetraploid rice crop may be able to give a good yield and its production may be useful in preparing various food products with high

nutritive value. If successful, the technique of tetraploid seed production and cultivation can be commercialised. The tetraploid rices require greater attention from the point of view of other scientific pursuits. The response of different genome groups in their tetraploid forms to the application of nitrogen would also be a very fascinating subject. For example, a diploid bearing a known dominant marker gene may be crossed with a tetraploid. The resulting diploids are expected to give plants with chromosomes varying from normal diploid to triploid. Some of these might turn out to be trisomics, with the extra chromosome being the one bearing the dominant marker gene. From the phenotypes, it may be possible to isolate the trisomic and use it for linkage studies.

Other important problems which await solution by the rice geneticists are the physiology of resistance of the rice plants to saline, drought, flood and deep water conditions. These important problems first require the evolution of suitable techniques to be employed for understanding the genetics of the rice plant in relation to these characters.

Other recent approaches include search for useful genes, controlling the hulling percentage; we have observed in our collections, cultures possessing up to 80% hulling percentage in a glabrous type. Attempts to utilize the useful characters present in *O. glaberrima* may also be made, e.g., high protein content and truncate ligule could be considered. In one of our experiments, a selection at higher nitrogen level has given the highest response and highest protein content.

APPENDIX III

A COMMUNICATION, ON CLONAL PROPAGATION, RELEASED IN 1964

(Reproduced from the Bharat Krishak Samaj year Book, 1964 pp. 299-301)

Clonal Propagation

The Central Rice Research Institute has recently announced a discovery of a new phenomenon observed in the rice plant. Its effect is that a single plant of rice (or a single stubble) in January can be multiplied to yield over 40 mds. of grains by the end of November during the same year. For example during 1963 the following results were obtained:—

Material	Grain Production
Single stubble of a rice variety, GEB-24	1,783 lb.
Single plant of a non-lodging fixed hybrid culture	2,874 lb.

Thus seed multiplication of an improved rice variety with absolute genetic purity is guaranteed which is the basis of an assured increase in rice yields by about 20 per cent. This effect is exhibited by repeated separation of tillers of the rice plants after regular intervals at the vegetative phase. As soon as the tillers are separated they show renewed vigour. The cause for such a phenomenon still remains to be worked out precisely. But this process works as if some hidden energy is released within the rice plant, resulting in its all round growth. These observations can be utilized in several other ways; for instance,

if the seed nursery is raised, a little early, say in May, individual seedlings may be multiplied to about 200 times or more by repeated separation of tillers, by the first week of August when the normal planting could be done; thus, where we will require 200 pounds of seed nursery, we can do that only with one pound of original seed stock and thereby clearly save 199 pounds of paddy for food consumption, if this practice of vegetative propagation or clonal propagation is practised. The yield of grain from such a crop, when the tillers are multiplied within the season (May to August), will also be nearly doubled, depending on the variety utilized, as compared with the normal crop, raised directly from the normal seedlings nearly one month old. This is because tiller plants are more vigorous, comparatively non-lodging and they resist diseases and pests as well, besides possessing other good characters. This method has been successfully demonstrated on the cultivators' holdings near about the Institute and they are thoroughly convinced of the utility of the practice in obtaining more rice per acre. An added advantage of this technique is that it gives us a great scope to exploit hybrid vigour even in a self-fertilized crop like rice to increase yields. In flood affected areas it has its special application.

From a handful of paddy grains an ordinary cultivator can meet his own requirement of pure seed of a particular variety at a negligible cost and he need not depend on seed supply of bulk seed of that variety from any other source. Thus seed multiplication and distribution, so cumbersome, time consuming and expensive in actual practice, is simplified by the vegetative propagation technique. Hardly a handful of grains need be obtained to meet his full requirement, adjusting the number of tiller separation according to the size of his holding.

APPENDIX IV

AN ABSTRACT FROM A SPECIFIC PLAN OF ACTION, FORMULATED IN 1983.

(A specific plan of action for increase in production of rice was drawn up on a suggestion made by the Prime Minister of India in 1983 (The late Mrs. Indira Gandhi, the then Prime Minister) and submitted to the source for consideration of the Indian Council of Agricultural Research, New Delhi).

* * *

It will also be demonstrated that the healthier seeds, obtained by clonal propagation for a full crop of rice to follow, give nearly 20 per cent higher production of any rice variety.

HYBRID CLONES FOR EXPLOITING HYBRID VIGOUR

Hybrid clones of F_1 plants between the cultivars or ecotypes of a major/popular rice variety will be distributed among the growers for raising seeds for F_2 generation by clonal technique to raise a full crop of rice by their usual method in the following season for taking advantage of hybrid vigour expressed in F_2 population. Enough information on the subject is available. F_2 population, under field condition gives, on the average, 50 to 60 per cent higher average production, as compared with the higher yielding parent, depending on the varieties, employed. As regards adaptability of the recombinants in local environments, they will behave in the same manner as their parents. The rice growers are intelligent enough to practise any method, once they are convinced that by a certain practice, they can get higher productivity,

as they are not afraid of manual labour. Hybridization work will be carried out by the trained field workers of the respective centres. Since the work will revolve round the local indigenous rice types, the rice growers will naturally take keen interest in this development.

SIGNIFICANCE OF RICE AS FOOD IN SOUTH-EAST ASIA

India's lead: India can become a world power in rice.

- (i) The story of this specific plan of action will not be complete if I do not record the following observations for information.

"Agriculture and rice or food and rice are synonymous in the languages of China and India". Rice is a key to the main problems of survival in many of the over-crowded areas in the Asian world.

"He who controls the supply of rice will control the destiny of the entire Asiatic orbit. The most important thing to the majority of the people of Asia is not capitalism, or socialism or any other political ideology but food which means life itself, and in most of Asia food is rice."

Planning for increase in production of rice, therefore, is a very sensitive subject which attracts the attention of the highest powers in the world, lest India controls Asia on the food front. It is rightly said, "Vigilance is the prize of liberty."

India is gifted with rice climate and is capable of attaining supremacy in this biological field and is capable of feeding millions in Asia and elsewhere, provided we apply our originality to take advantage of Nature's gift and allow the gifted rice researchers with absolute freedom of thought and action

to go ahead with rice genetic engineering and do not interfere with the farmers' choice of their varieties which possess hardiness and adaptability to their environment and environmental stress and which may be further improved. It is also known that some rice varieties of India have been proving very useful in breeding programmes in raising the yield potential of rice of temperate regions in the South-East Asia to improve the *Japonica* varieties *e.g.*, the yield potential of rice in Korea has been increased through such a programme in recent years. Such a lead can be further strengthened if the rice germplasm of India is well preserved, studied and supplied *directly* to countries in the temperate regions and the fringe areas from the natural habitat, an item to be included in this specific plan of action.

APPENDIX V

IN VIVO AND IN VITRO CLONAL PROPAGATION IN RICE

R.H. Richharia and K. Pavithran

Plant propagation has been a fundamental occupation of mankind adopted from time immemorial for various requirements of food and shelter. Domestication and propagation of plants led to selection of plant species. Cultivated plants originated as human selection of superior genotypes of hybrids or natural mutants. Improved forms were maintained through various techniques of plant propagation, asexual/vegetative or sexual. Vegetative propagation or cloning preserves the unique characteristics that made them useful to man, while seed propagation leads to the immediate loss of the unique characteristics of such selections, especially in the case of cross pollinated crops.

Clonal propagation:

Cloning in plants refers to production of genotypically identical individuals from a single stock by vegetative propagation *in vivo* or by regeneration of somatic or generative cells *in vitro*. Now it seems possible or feasible to clone almost all organisms, from microbes to man or, to be more precise, from genes to humans. Clonal propagation has been successfully practised commercially in certain crops like rubber, apple, pear trees and cashew or mango and others (Hartman and Kester, 1975) and has been extended to certain cereals like rice (Richharia, 1960). Clones require proper maintenance and its life span is theoretically unlimited, if so maintained and multiplied continuously. New seedling of the succeeding

sexual cycle is resulted from the process of cyclic juvenescence resulting from sporogenesis and fertilization. Juvenescence is achieved by continuous cloning also (Brink, 1962). Further, senescence is delayed due to the rejuvenation process of cloning. The callus tissue developed from a meristem or cell *in vitro* undergoes embryonization and subsequent regeneration into seedlings and develop into adult plants. However, sometimes juvenile characteristics can persist for several vegetative generations, as has been found with the nucellar clones in citrus (Cameron *et al.*, 1957) and with the *in vivo* clones in rice (Pavithran, 1975). Vegetative propagation is carried out in plants by different techniques including apomixis (Calusen and Heisey, 1958; Watson and Clausen, 1961; Hartman and Kester, 1975) and micropropagation (Hartman and Kester, 1975; Oono, 1984; Zapata, 1985). However, genetic barriers exist among plant species for response and efficacy to vegetative propagation. Wide variability exists among rice varieties in their response to tiller-propagation (Richharia, 1960; Richharia *et al.*, 1964; Pavithran, 1975) or response to tissue culture (Oono, 1984; Zapata, 1985). Callus induction frequency in *japonica* rice has been reported to be much higher than that in *indica* (Oono, 1984). However, with the basic knowledge of vegetative propagation which is the earliest ancestral mode of reproduction in plants, tremendous advancement in propagation technology has been achieved today through expensive sophisticated methods of science and technology. As a result, molecular cloning has been made possible with isolated genes *in vitro*. Cloning of isolated genes *in vitro* and transfer them to concerned organism/s at will, perhaps, will be a common place phenomenon in the near future (Oono, 1984; Gerlach *et al.*, 1985; Salazar *et al.*, 1985 and *others*). However, the significant value of simple and low cost techniques such as mechanical *in vivo*

vegetative propagation techniques deserve considerable attention, for such techniques can be practised easily at various levels of plant propagation. These techniques, no doubt, deserve improvement in the light of new knowledge gained in science and technology, instead of its total replacement by costly and cumbersome methods. Such improvements, if made possible, would render better help to small level farmers of our country, who constitute the bulk of the farming community, and also to the researchers in low cost clonal production especially in suitable plant species like rice. The use of *in vitro* cloning may be restricted to those species not amenable to easy vegetative propagation and/or sexual propagation and also to produce somaclonal variations (Larkin and Scowcroft, 1981; Scowcroft *et al.*, 1985).

Clonal propagation by growing separated tillers established thousands of successfully developed tiller plants within reasonable time with reliable genetic purity in rice (Richharia and Misro, 1960; Tanaka, 1961; Richharia *et al.*, 1964; Pavithran, 1968, 1975). Such clones have been used to establish and maintain F_1 plants of various crosses, to maintain blast spores for studying physiological races, to multiply male steriles and other mutants like nude panicle plants, to exploit hybrid vigour and to maintain genetic purity of the breeding materials and so on (Capinpin and Villamayor, 1948; Richharia, 1960; 1962. Richharia and Misro, 1960; Richharia *et al.*, 1964; Pavithran, 1975). The agronomic significance of vegetatively propagated crop (Richharia *et al.*, 1964) and its added efficacy in nutritional uptake as compared to seed plants (Richharia and Patnaik, 1963) have been earlier recognised. The utility of clonal material in studying inheritance of photoperiodic response and certain other physiological characters in rice has also been emphasised (Richharia and Misro, 1960). It is possible to raise fully developed plants from

separated tillers of any order/rank irrespective of their age and stage of development, probably, due to their autotrophic status after detachment (Tanaka, 1961). The significance of clone in the study of phenotypic plasticity and expressivity of morphological characters has been emphasised by many workers in several plants including rice (Jones and Turril, 1938; Clausen and Heisey, 1958; Muntzing, 1961; Wilkins, 1963; Ramanujam and Kumar, 1963; Sang, 1963; Bradshaw, 1964; Allard and Bradshaw, 1964; Pavithran, 1975). Moreover, the age old practice of ratoon cropping in rice is based on its ability in tiller propagation and perennation.

Ratoon cropping rice is a means by which the perennating tiller plants are exploited after harvest of the main crop, raised from seeds. Perennation is an established ancestral character of the rice plant. *Oryza perennis* which is said to be the wild progenitor of the cultivated species, is essentially a perennial grass growing in tropical swamps and *O. sativa* L., the cultivated species, is an annual crop and most of its varieties retain the perennating habit, as they can be ratooned (Oka and Morishima, 1967; Oka, 1976). The distinctive adaptive characteristics of both the perennial and the annual types are presented in Table 1. Both types are allopatric having different adaptive strategies which allow the perennial types to thrive well in wet low lands and the annual types in the uplands. However, no reproductive isolation exists between them and an intermediate type is observed under certain situations (Morishima *et al.*, 1980; Sano and Morishima, 1982). The importance of ratoonability in rice has been recently recognised in a workshop held in Bangalore in 1986 under the joint auspices of the IRRI, IARI and the Agricultural University, Bangalore, and certain priority areas of research and development were identified for varietal improvement of ratooning habit in rice including germ plasm conservation,

agronomy and genetics of ratoonability. This immediate awareness of the need for understanding of this useful ancestral characteristic seems to have emerged out of the earlier neglect of this important character of evolutionary significance and survival value for the plant in any eventuality. From the breeding point of view, if early duration varieties capable of ratooning could be selected, there is plenty of time to grow ratoon crop of rice before the onset of cold period and selection of varieties for ratoonability should be carried out (Trinh, 1984), perhaps, as an effective complementary approach to tiller-propagation.

Genetic purity and *in vitro* cloning:

Genetic purity of the material used in breeding experiments is an alarming demand of the breeders and geneticists. Genetic sustainability and maintenance of the elite genotypes, hybrids, male sterile plants, autopolyploids, polyploids and aneuploids and so on are challenging situations for plant breeders to overcome by sure, suitable and cheaper techniques. *In vivo* vegetative propagation techniques satisfy this need to a great extent (Richharia, 1960; Richharia *et al.*, 1964; Pavithran, 1968; Hartman and Kester, 1975).

Modern *in vitro* cultural techniques have been advanced to that extend to subject somatic tissues and generative cells to produce callus and subsequent embryonisation and regeneration into seedlings under controlled conditions of nutrition, light and temperature. However, 2,4-D has been reported to induce variations termed as 'somaclonal variations' (Larkin and Scowcroft, 1981 and Larkin *et al.*, 1984; Scowcroft *et al.*, 1985). Somaclonal variation refers to the enhanced genetic variability in plants regenerated from tissue culture and has been observed widespread in most major crop species (Scowcroft *et al.*, 1985). Under *in vitro* culture

the genetic purity of the source material for cloning by regeneration is not often assured, as genomic, chromosomal, genic and cytoplasmic or physiological effects occur quite frequently (Novoak *et al.*, 1978; Singh, 1983; Oono, 1984). *In vitro* clonal production has not been fully standardised in many cases. Even if tissue and pollen cultures are standardised in a few cases, the chromosomal and genetic instability under tissue culture poses problems (Singh, 1983). Oono (1984) and IRRI (1985) have recorded high degree of genetic instability in tissue and cell cultures used for regeneration and clonal propagation in many species, including cereals. However, in aseptic culture, cells have regenerated into entire plants, identical to the original parental cell source as in tobacco (Vasil and Hilebrandt, 1965), carrot (Steward *et al.*, 1963), orchids and tomato (Anchora, 1979). As has been indicated, collections (regenerated plants) must ultimately be evaluated and utilised, since tissue culture, at best, would only be a means of conservation, and for evaluation purpose and breeding work the collections must be established in the field according to the recommended cultivation practices (Singh, 1983). This proposal deserves consideration from the practical point of view and it seems to be a caution against indiscriminate adoption of *in vitro* propagation, irrespective of its actual relevance.

In vitro propagation seems to be only an extension of *in vivo* vegetative propagation, utilizing highly sophisticated technology. A recent seminar held in the IRRI in 1984 on 'Biotechnology in International Agricultural Research' brought forth the following conclusions and recommendations especially on *in vitro* micropropagation in relation to biotechnology.

In vitro propagation has wide application in both clonally and sexually propagated plants. It is estimated that by 1988,

more than 3000 plant species might be propagated through *in vitro* cultures, from the meagre number of 30 species known in 1968 and 300 species in 1978. *In vitro* propagation has been recognised as a basic requirement for the successful implementation of all aspects of plant biotechnology with the possible exception of some by-product application. However, all these are also applicable to *in vivo* vegetative propagation methods at least in certain crop plants like rice. Tanaka (1971) studied the variability of vegetatively propagated haploids in rice exposed to chronic gamma rays and obtained diploid lines with the frequency of 2.3×10^{-2} . It has also been concluded that the genetic variability of the regenerated plants from haploid somatic tissues appears to be larger than variability resulting from chronic irradiation. This, on the other hand, indicates the genotypic stability of the *in vivo* vegetative propagated materials.

Future progress on cereals and grain legumes will require intensified crop specific work and understanding of the biochemical basis for plant regeneration and its control in order to maintain genotypic stability of the clones. *In vitro* propagation may release instability manifested as somaclonal variation (Larkin and Scowcroft, 1981). This appears to be related to the species and the route to regeneration. Although of potential value in plant breeding, somaclonal variation is disadvantageous in the clonal propagation of elite and other specific genotypes of breeding significance. Moreover, efficient criteria to evaluate the phenotypic stability of cultures and regenerated plants are yet to be developed and economical technologies for mass propagation, appropriate to developing countries, are to be researched yet (IRRI, 1985).

Somaclonal variation is an alternate source of genetic variability in plants. Such variations have several uses in plant breeding programs of disease elimination (Roca, 1985),

germplasm conservation (Wither and Williams, 1985), micropropagation and haploid production ((Pannetier *et al.*, 1985) and mutation breeding (Anchora, 1985). However, a comparison of *in vivo* vegetative propagation and *in vitro* propagation has revealed (Table 2) that both the techniques are useful as aids in plant breeding and propagation at different levels of application. However, vegetative propagation technique deserves more attention that it received till date in the new context in order to evolve a better and cheaper technique for rapid propagation of plants like rice ensuring greater genetic stability of the clones. It may also be mentioned that by judicious administration of appropriate mutagens more stable variations can be induced in clonally propagated material *in vivo*, than in the case of *in vitro* cultures, even though the number of such variations would be limited.

CONCLUSIONS:

Clones can be produced by *in vivo* and *in vitro* techniques. Now *in vitro* cloning seems possible with all organisms or even with isolated genes.

Continuous cloning leads to juvenescence in plants. Clonability is genetical, as seen in rice and certain other plants.

Micropropagation or *in vitro* cloning does not guarantee maintenance of genetic purity due to the frequent occurrence of somaclonal variations. *In vivo* cloning ensures genetic purity of the source material.

Step-wise improvement of an established cultivar without risking its basic genetic constitution by using somaclonal variation is said to be difficult presently.

Simple low-cost *in vivo* clonal techniques must be improved with new technologies known, instead of its total replacement by costly and cumbersome methods of uncertain consequences.

In vivo clonal propagation has been successfully applied in rice for different objectives. All available *in vitro* clonal collections in rice and similar crops must be ultimately evaluated according to the recommended cultivation practices. Of course, *in vitro* cloning has relevance in biotechnology and genetic engineering. Both *in vivo* and *in vitro* clonal techniques are useful tools, in different contexts, in plant propagation and breeding, and one should not be overlooked or replaced by the other.

Table 1. Adaptive characteristics of perennial and annual types of rice

perennial rice	annual rice
Adapted to deep swamps	Adapted to shallow and temporary swamps
High asexual propagating ability	Low asexual propagating ability
Low seed productivity	High rate of seed productivity
Weak seed dormancy	Strong seed dormancy
Large anthers	Small anthers
High crossing rate	Low crossing rate
High sterility	Low sterility
High floating ability	Low floating ability
Low drought resistance	High drought resistance
Dominant in low lands	Dominant in uplands
Allogamous	Autogamous

After Oka, H.I. and H. Morishima, 1967.

Table 2. Comparison between *in vivo* and *in vitro* cloning

<i>in vivo</i> cloning	<i>in vitro</i> cloning
Easy to practise even by farmers	Sophisticated techniques needed
Tiller-plant production depends on genotypic and splitting frequency	seedling production depends on rate of successful regeneration
Genetic purity of the clone usually assured.	Genetic purity not assured
Ratoon cropping possible	not practicable to <i>in vitro</i> system
Tillering can also be induced	regeneration is also inducible
Tillering habit genetical	regenerability genetical
Uniform plants of equal maturity and ability to establish can be produced	Plants are not of uniform maturity and are comparatively weaker to establish
Mutants are produced least	Mutations at genomic, chromosomal and genic levels and physiological levels occur
Least expensive	Highly expensive

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